

Transactions of the Royal Society of South Australia Incorporated

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THE SPIONIDAE OF SOUTH AUSTRALIA (ANNELIDA: POLYCHAETA)

BY *P. A. HUTCHINGS & P. S. TURVEY*

Summary

Five new species of Spionidae, *Aquilaspio pyramidalis*, *Scoelepis* (S.) *bifida*, *Scoelepis* (N.) *edmondsi*, *Spio tridentata* and *Boccardia fleckera* are described. Descriptions are given of fourteen previously described species of Spionidae occurring intertidally in South Australia, together with their known geographical range. Two species of *Pseudopolydora* are described only to genus. A Key to all species is provided.

THE SPIONIDAE OF SOUTH AUSTRALIA (ANNELIDA: POLYCHAETA)

by P. A. HUTCHINGS & S. P. TURVEY*

Summary

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Five new species of Spionidae, *Aquilaspio pyramidalis*, *Scolecopsis* (S.) *bifida*, *Scolecopsis* (N.) *edmondsi*, *Spio tridentata* and *Baccardia fleckera* are described. Descriptions are given of fourteen previously described species of Spionidae occurring intertidally in South Australia, together with their known geographical range. Two species of *Pseudopolydora* are described only to genus. A Key to all species is provided.

KEY WORDS: Taxonomy, Polychaeta, Spionidae, South Australia, Key.

Introduction

In 1979 one of us (PH) made extensive collections of South Australian polychaetes, concentrating on estuarine and intertidal areas. Although Blake & Kudenov (1978) have recently undertaken a major review of the spionids from SE Australia, we have found an additional five new species. This probably indicates the diversity of the spionids in southern and south eastern Australia, and we suspect that many more species remain to be described.

In addition to describing five new species, we have included a short diagnostic account of each genus and of previously described species occurring in South Australia. Species identified from the key should be checked carefully against the descriptions, in particular the setigers on which setal changes occur and the detail of the setal structure. This is particularly important for non-South Australian material, where other references such as Blake & Kudenov (1978) and Hartmann-Schröder (1979, 1980, 1981) should be consulted.

Materials and Methods

Station data have been coded and tabulated (Table 1) and the codes used in the Material examined section of each species description. Registration numbers of Australian Museum material has been abbreviated to W. plus number. Paratypes have been deposited wherever possible at the Allan Hancock Foundation, Los Angeles (AHF), British Museum (Natural History), London (BMNH) and The National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM). Other abbreviations used are as follows: HZM, Zoo-

logisches Institut und Zoologisches Museum der Universität, Hamburg; KM, Zoologisk Museum, Copenhagen; NMV, National Museum of Victoria, Melbourne; SAM, South Australian Museum, Adelaide.

The Australian distribution of each species has been given using Day & Hutchings (1979) checklist and Blake & Kudenov (1978). The localities are arranged geographically from west to east, and along the east coast of Australia from south to north. Additional locality data from subsequent publications are marked with an asterisk.

In general we have only cited major Australian references. Full synonymies are given by Blake & Kudenov (1978) and Day & Hutchings (1979).

We have followed Foster (1971) in accepting the various genera within the *Prionospio* complex which she recognised based mainly on the type of branchiae present. We believe this is a useful division.

Key to the South Australian Spionidae (after Blake & Kudenov, 1978)

1. Setiger 5 modified, with specialised setae 2
Setiger 5 not modified, without specialised setae 11
2. (1) Branchiae beginning on setiger 2 3
..... *Baccardia*
Branchiae beginning on setigers 6-12. 5
3. (2) Prostomium entire *B. proboscidea* 4
Prostomium deeply incised
4. (3) Neurosetal hooded hooks from setiger 7; setiger 5 with simple falcate spines and spines with concave cup containing bluntly conical tooth B. chilensis
Neurosetal hooded hooks from setiger 11; setiger 5 with curved falcate smooth spines and brush tipped setae B. fleckera n.sp.

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5. (2) Setiger 5 slightly modified, with prominent parapodia, major spines of 2 types arranged in V or J shaped row *Pseudopolydora* 6
Setiger 5 greatly modified with reduced parapodia, and 1 type of spine arranged in curved row *Polydora* 9
6. (5) Prostomium entire 7
Prostomium deeply incised 8
7. (6) Neurosetal hooded hooks, bidentate from setiger 8 *P. paucibranchiata*
Neurosetal hooded hooks, multi-dentate from setiger 7 *Pseudopolydora* sp. 2
8. (6) Modified setae on setiger 5 pennoned and simple spines *P. antennata*
Modified setae on setiger 5 falcate pennoned spines *Pseudopolydora* sp. 1
9. (5) Hooded hooks without constriction on shaft; setiger 5 with major spines with subterminal boss, companion setae bilimbate *P. socialis*
Hooded hooks with constriction on shaft; setiger 5 with setae otherwise 10
10. (9) Prostomium weakly incised; setiger 5 with falcate spines with large sub-terminal flange, companion setae bilimbate *P. hoptuna*
Prostomium incised with 2 widely separated lobes; setiger 5 with curved spines with prominent subterminal tooth and feathered companion setae *P. ligni*
11. (1) Prostomium distally pointed with or without subdistal lateral horns 12
Prostomium not distally pointed, with or without distal lateral or frontal horns, broadly rounded or incised on anterior margin 15
12. (11) Branchiae fused to dorsal lamellae at least basally, continuing to end of body *Scolecopsis* 13
Branchiae completely free from dorsal lamellae, present on variable number of anterior setigers, absent posteriorly *Aonides oxycephala*
13. (12) Notosetae all capillaries, at least until setiger 93 14
Notosetae initially capillaries, bidentate hooded hooks from setiger 38-56 *S. corniculata*
14. (13) Neurosetal hooded hooks bidentate from setiger 36 *S. bifida* n.sp.
Neurosetal hooded hooks tridentate from setiger 43 *S. edmondsi* n.sp.
15. (11) Branchiae concentrated in 1-22 anterior setigers, absent posteriorly 16
Branchiae present over most of body length 20
16. (15) Branchiae all cirriform, 10 pairs *Minuspia cirriforma*
Branchiae not all cirriform, 3-4 pairs 17
17. (16) Branchiae all pinnate *Aquilaspio* 18
Branchiae pinnate and cirriform *Prionospio multieristata*
18. (17) Three pairs of branchiae *Aquilaspio aucklandica*
Four pairs of branchiae 19
19. (18) Rounded neuropodial lamella on setiger 1 *Aquilaspio multipinnulata*
Neuropodium of setiger 1 inflated, pyramidal in shape *Aquilaspio pyramidalis* n.sp.
20. (15) Branchiae beginning on setiger 1 anteriorly fused to notopodial lamellae, neuropodial hooks from setiger 28 *Spio tridentata* n.sp.
Branchiae beginning on setiger 2 stout cirriform completely free from notopodia; neuropodial hooks from setiger 9 *Microspio granulata*

Scolecopsis (Blainville) (emended Pettibone))
Prostomium pointed anteriorly and posteriorly. Peristomium forming hood about prostomium. Branchiae from setiger 2 to near end of body, more or less completely fused to notopodial lamellae at least anteriorly. Neuropodial lamellae uni- or bilobed. Neuropodial hooks present in far posterior or absent. Hooks hooded, entire, bi- to quadridentate.

Scolecopsis (*Scolecopsis*) *bifida* n.sp.

FIG. 1a-g.

Scolecopsis lamellicincta Blake & Kudenov, 1978: 176-178, fig. 1a-k (in part).

Holotype: S.A. 09C (W.19283).

Paratypes: 09C, 2 (W.19284), 1 (USNM 074899), 1 (BMNH ZB-1982.76), 32C, 8 (W.19285), 1 (AHF POLY 1383).

Other material examined: *Holotype* of *Scolecopsis lamellicincta* Blake & Kudenov (NMV G102) and *Paratype* (NMV G2990) Westernport Bay, Vic. (SAM E1577) Elliston, S.A. *Holotype* of *Pseudonerine antipoda* Augener (KM) Pegasus Bay, Stewart Island, New Zealand.

Description: *Holotype* posteriorly incomplete, partially broken between setigers 63-64; 59 mm long and 4.2 mm wide at about setiger 40, for a total of 93 setigers. *Paratype* material all incomplete posteriorly, with following ranges of dimensions: 40 mm long, 2.5 mm wide for 87 setigers; 25 mm long, 2.0 mm wide for 70 setigers; 18 mm long, 1.5 mm

TABLE 1. *Collection data*

Locality, collector and date	Latitude/ longitude (Deg. Min.)	Habitat	Code
Port Augusta. Hutchings, 14.iii.1979	32-30/137-46	Sand on mudflats in front of mangroves, under bridge	01A
Streaky Bay, near caravan park. Hutchings, 13.iii.1979	32-48/134-13	Mussell clumps at mid tide level on mud flats	02A
		Mud flats, <i>Posidonia</i>	02B
		Mud sievings, <i>Posidonia</i>	02C
		<i>Posidonia</i> and <i>Zostera</i> sievings	02D
		Fauna associated with <i>Zostera</i>	03A
		Sands sievings	03B
		Sand sievings, <i>Posidonia</i>	03C
		Under boulders	03D
		<i>Posidonia</i> and <i>Zostera</i> sievings	03E
		Sand sievings among <i>Posidonia</i> and <i>Zostera</i>	03F
Speeds Point, Streaky Bay. Hutchings, 14.iii.1979	32-48/134-13	Algal washings	04A
Port Kenny, Venus Bay. Hutchings, 12.iii.1979	33-10/134-41	<i>Zostera</i> sievings	04B
Venus Bay, village. Hutchings, 12.iii.1979	33-14/134-40	Mussel clumps at mid-tide level	05A
		Algal mat on reef, south of village	06A
		Sand sievings	06B
		Fauna on jetty piles	06C
Elliston, reef at southern end of town. Hutchings, 12.iii.1979	33-39/134-53	Under rocks on low tide reef flat	07A
		Algae from low tide reef flat	07B
		Sand sievings at low tide	07C
		Algal washings	08A
Elliston, reef just past post-office. Hutchings, 12.iii.1979	33-39/134-53		
Elliston, jetty. Hutchings, 12.iii.1979	33-39/134-53	Amongst <i>Guleplaria</i> on jetty piles	09A
		Nearby rocks, encrusting algae	09B
		Sand sievings	09C
Kellidie Bay. Hutchings, 11.iii.1979	34-36/135-29	Mussel clumps at mid-tide level	10A
		<i>Zostera</i> and sand sievings	10B
		<i>Zostera</i> sievings	11A
Porter Bay, Port Lincoln, near boat ramp. Hutchings, 10.iii.1979	34-44/135-53		
Torrens Island, Adelaide Power Station. Hutchings, 7.iii.1979	34-47/138-32	Mudflats in front of thermal effluent (up to 42°C)	12A
		Mud flats in front of mangroves	12B
		Mud flats in front of mangroves with patchy <i>Zostera</i>	12C
Flinders Cairn, Port Lincoln. Hutchings, 10.iii.1979	34-49/135-47	Sand at low tide level	13A
		Mussel clumps at mid-tide level	13B
Sleaford Mere. Hutchings, 10.iii.1979	34-50/135-45	Mud, salinity 20‰	14A
Sleaford Bay. Hutchings, 10.iii.1979	34-54/135-47	Algae on ocean side of bay	15A
Sellicks Beach, reef to north. Hutchings, 16.iii.1979	35-20/138-27	Algal washings	16A
		Sievings in <i>Amphibolis</i>	16B
		Sand sievings	16C
		Sand sievings near <i>Arenicola</i>	16D
		Fauna attached to jetty piles	17A
Rapid Bay, jetty between Normanville, and Second Valley. Hutchings, 8.iii.1979	35-32/138-11		
Victor Harbor, just behind bluff. Hutchings, 16.iii.1979	35-33/138-38	Crevice fauna	18A
		Algal washings	18B
Emu Bay, Kangaroo Island, adjacent to old jetty. Hutchings, 1.iii.1979	35-35/137-31	Coralline algae washings	19A
		Crevice fauna	19B
		Algal washings	19C
		Under rocks beside jetty	19D
		<i>Posidonia</i> sievings	19E
Stokes Bay, Kangaroo Island. Hutchings & Butler, 5.iii.1979	35-37/137-12	Algal washings	20A
Stokes Bay, Kangaroo Island. Handley, 4.iii.1976	35-37/137-12	Sand sievings	20B
		Algae at low-tide level	21A
Bay of Shoals, Kangaroo Island. Hutchings & Edmonds, 1.iii.1979	35-36/137-37	Under rocks at low tide level	21B
		<i>Zostera</i> sievings	22A

3 km SW of Cape Rouge, Handley, 7.iii.1978		Sand flats verging into <i>Posidonia</i> and <i>Hormosira</i>	22B
Bay of Shoals, low-tide. Hoese, iii.1979		<i>Posidonia</i> , <i>Zostera</i> , mud and sand	22C
Snellings Beach, mouth of Middle River, Kangaroo Island.	35-42/137-06	Algal holdfasts and crevice fauna	23A
Hutchings & Butler, 5.iii.1979		Sand sievings	23B
Penneshaw jetty, Kangaroo Island. Handley, 9.iii.1978	35-43/137-56	In sponges on boom piles at 5 m, and under rocks	24A
Western River Cove, Kangaroo Island, Handley, 3.iii.1978	35-43/136-56	Sheltered rock pool, under rocks and algae	25A
Redbanks, Nepean River, Kangaroo Island, Lock and Yoo, 8.iii.1978	35-44/137-43	Sheltered shallow bay at low level	26A
Muston Point, American River, Kangaroo Island, old wharf. Hutchings, 2.iii.1979	35-47/137-46	Clumps of sponge at 5 m in fast flowing channel with many <i>Pinna</i> Sand, sponges, and sandy conglom- erate rock at 5 m in fast-flowing channel	27A 27B
American River, Kangaroo Island, top of river just below turn-off to Pennington Bay, Hutchings, 3.iii.1978	35-47/137-46	<i>Zostera</i> sievings	27C
Pelican Lagoon, south side, Kangaroo Island, Handley, 8.iii.1978	35-40/137-45	Surface detritus and algae	28A
Cape du Couedic, Kangaroo Island. Hutchings & Butler, 4.iii.1979	36-03/136-41	Under rocks and <i>Hormosira</i> in front of salt marsh, at mid-tide level	29A
Harriet River estuary, Vivonne Bay, Kangaroo Island. Yoo and Handley, 2.iii.1978	35-58/137-09	Exposed beach, algal holdfasts	30A
Hanson Bay, Kangaroo Island, Hutchings & Butler, 4.iii.1978	36-02/136-51	Exposed beach, coralline algae and algal holdfasts	30B
Cape Dromby, near obelisk. Yoo, 2.ii.1978	37-10/139-44	Exposed beach, coralline algae washings	30C
Cape Northumberland, on west side. Yoo, Loch and Handley, 27.iii.1978	38-04/140-40	Exposed reef, algal holdfasts	30D
		Exposed reef, coralline algae	30E
		Sievings at low-tide level	31A
		Algal holdfasts on reef flat	32A
		Closed mouth of South West River, salinity 30‰	32B
		Exposed beach, sand sievings	32C
		Algae from pool on exposed rock platform.	33A
		Sievings in low <i>Zostera</i> patches at low-tide	33B
		Sheltered pools behind exposed rock platform at low tide	34A

wide for 70 setigers; 15 mm long, 2.0 mm wide for 70 setigers; 10 mm long, 1.5 mm wide for 37 setigers; 6 mm long, 2.0 mm wide for 20 setigers; 20 mm long, 2.0 mm wide for 66 setigers; 30 mm long, 2.5 mm wide for 79 setigers and 45 mm long, 2.0 mm wide for 110 segments. Body broadly rectangular in cross-section, broadest in mid-section, tapering anteriorly and posteriorly. Colour pinkish brown in alcohol. Prostomium bulbous anteriorly tapering to acute point; posteriorly forming small, high, attached keel-like caruncle extending to middle of setiger 1 (Fig. 1a); two pairs of eyes arranged in oblique row on each side of base of caruncle, obscured by peristomial hood; occipital tentacle absent. Peristomium forming high lateral hood about posterior part of prostomium, becoming lower

anteriorly; palps thick, smooth, tapering progressively with conspicuous basal palpophore or sheath extending to setiger 11 (left)-13 (right). Setiger 1 reduced, with notopodial lamellae small, thick, bluntly triangular, neuropodial lamellae smaller than notopodial, rounded, cup-shaped, but noto- and neurosetae present. Branchiae from setiger 2, thick, cirriform, elongating to reach approximately twice initial length by about setiger 10 then decreasing slightly towards end of fragment, each branchial pair connected across dorsum by narrow ciliated ridge; anterior postsetal notopodial lamellae extend dorsally as membranous borders along lateral margins of branchiae, becoming separate only at far distal extremity (Fig. 1b); branchiae only slightly longer than lamellae giving combined lamellae-branchiae

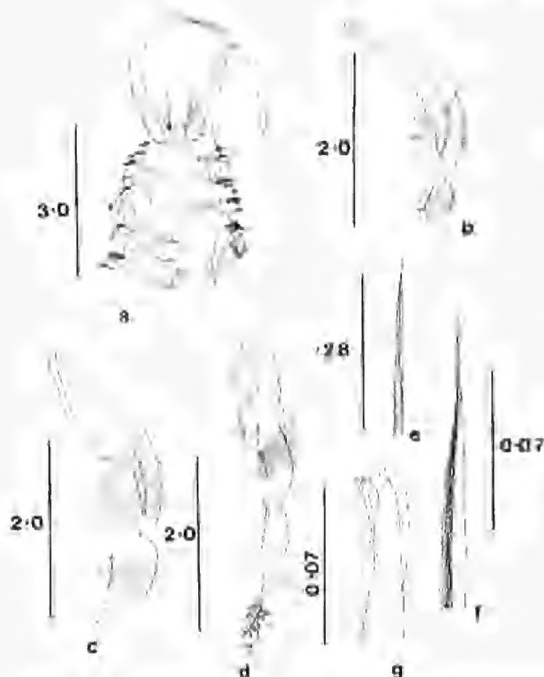


Fig. 1. *Scolelepis (S.) bifida* n.sp. a. anterior end, dorsal view. b. anterior view of 5th parapodium. c. anterior view of 20th parapodium. d. anterior view of 40th parapodium. e-f. sabre seta at $\times 25$ and $\times 100$ magnification. g. hooded hook. Scales in mm.

appearance of being distally bifid, with small, flattened points (Fig. 1c), from about setiger 30–40 free tips of branchiae become more elongate, digitiform, initially curving around medio-distal margins of lamellae before continuing as free processes (Fig. 1d); lamellae becoming broader and more rounded distally, strongly folded in all but far anterior setigers. Presetal notopodial lamellae low, rounded ridges in anterior setigers, becoming inconspicuous posteriorly, while body wall supporting notosetae simultaneously becoming raised ridge. Postsetal neuropodial lamellae anteriorly semicircular in outline, becoming bi-lobed by setiger 30; ventral neuropodial lobe small, semicircular in profile becoming displaced ventrally behind ventral extremity of neurosetal fascicle; dorsal neuropodial lobe rapidly forming a low, elongate interramal lamella, overlapping with notopodial lamella after a few setigers then becoming progressively separated posteriorly. Presetal neuropodial lamella similar to notopodial. Notosetae all capillaries at least to setiger 93. Anterior notosetae arranged in two broad rows, with those in

those in posterior rows longer, narrower but still stout, each seta unilimbate or appearing to be without sheath or wings; both types with shafts with distal fine granulations and transparent limbate processes having faint oblique striations; notosetae reducing to single row at about setiger 30 with broad vertical group of shorter capillaries situated ventrally and narrow horizontal group of long capillaries located dorsally, these two groups becoming variably separated by a narrow space which may include several very short, fine, unsheathed capillaries; capillaries becoming less robust with granulations barely noticeable, in far posterior setigers. Neurosetae anteriorly similar to notosetae except most ventral capillaries developing into a partially separate fascicle of 3–7 sabre setae over first 3–4 setigers (Fig. 1e–f); sabre setae similar to unilimbate capillaries except shorter with shafts coarsely granular distally in posterior setigers; capillaries in posterior neuropodial fascicles gradually replaced by hooded hooks from setiger 36; initially with only 2 hooks, then becoming more numerous forming broad fascicle of 7–10 hooks and 3–5 small bundles of capillaries; capillaries located between hooks in dorsal part of fascicle; hooded hooks worn, bidentate, with shafts greatly thickened in basal region after emergence from body wall (Fig. 1g). Pygidium and other posterior structures missing.

The paratype material exhibits some variation from the holotype including eyes not visible, and palps extending to setiger 11–21; neuropodial lamellae bi-lobed from setiger 23–34; notopodial lamellae variably but noticeably folded at least posteriorly, frequently in all setigers. Hooded hooks in neuropodia from setiger 32–36, 5–10 in number.

Comments: *Scolelepis bifida* n.sp. belongs to the sub-genus *Scolelepis* as defined by Pettibone (1963). *Scolelepis bifida* n.sp. is similar to *S. squamata* (Müller, 1806) and *S. blakei* Hartmann-Schröder, 1980 in that setiger 1 has notosetae, postsetal neuropodial lamellae are divided posteriorly, and hooded hooks are bidentate. *Scolelepis squamata* differs in that the postsetal notopodial lamellae extend only slightly along the branchiae, the dorsal lobes of the neuropodial lamellae do not form long, low interramal lamellae and the hooded hooks are not basally swollen. *Scolelepis blakei* differs in a similar manner and in addition has a trifold prostomium. Two other species of *Scolelepis*

recently described from Western Australia, *S. (S.) halihalensis* Hartmann-Schröder, 1979 and *S. (S.) kudenovi* Hartmann-Schröder, 1981 can be easily distinguished from *S. bifida* n.sp. by the absence of notosetae on setiger 1 in these two species.

Scolecopsis lamellicincta Blake & Kudenov 1978 was described from SE Australia, including S.A. as having unidentate hooded hooks. The types of this species have been re-examined and the hooded hooks are not unidentate but have 1 large tooth plus 2 smaller teeth, almost forming a cusp shaped arrangement. Also in *S. lamellicincta* the postsetal neuropodial lobe becomes a separate entity whereas in *S. bifida* n.sp., this lobe remains attached. One of the paratypes (SAM B1577) was collected from Elliston Jetty, S.A. and has bifid hooded hooks and parapodial structures similar to *S. bifida* n.sp., and is referred to this species. Hartmann-Schröder (1980) described *S. lamellicincta* from Onslow, W.A. and also figures unidentate hooded hooks, and may represent an undescribed species. The type of *Scolecopsis antipoda* (Augener) has been examined, however the type consists of numerous small fragments, but the anterior fragment clearly differs from *S. bifida* n. sp. in the shape of the prostomium and the anterior gill structure.

The prostomium of *S. antipoda* is rounded in comparison to *S. bifida* n.sp. in which the prostomium is bulbous and anteriorly tapering to an acute point. The anterior branchiae of *S. antipoda* are cylindrical with a small dorsal terminal lamellae whereas in *S. bifida* n.sp. the branchiae are simple and cylindrical.

Etymology: The specific name *bifida* refers to the bi-lobed nature of the postsetal neuropodial lamella from middle setigers onwards.

Australian distribution: S.A. (Elliston).

Habitat: Sandy substrates.

***Scolecopsis (Scolecopsis) carunculata* Blake & Kudenov**

Scolecopsis carunculata Blake & Kudenov 1978: 178-180, fig. 2a-i.

Material examined: S.A. 06H, 4 (W.19313), 07C, 2 (W.19308), 16D, 3 (W.19309), 19E, 4 (W.19312), 20B, 3 (W.19311), 23H, 5 (W.19310).

Description: Size range of entire specimens of 66-75 setigers; 16-20 mm long, 1.0-1.4 mm wide; posteriorly incomplete specimens up to 3.0 mm wide. Prostomium slightly fusiform pointed anteriorly and posteriorly; posterior

part of prostomium free of dorsum, forming caruncle frequently elevated, extending to posterior margin of setiger 2. Setiger 1 with postsetal notopodial lamellae and notosetae present. Notopodial lamellae fused to branchiae except distally in anterior setigers, becoming more separated posteriorly. Neuropodial postsetal lamellae single lobed anteriorly, becoming bilobed at setiger 24-37. Anterior notosetae all capillaries, bidentate hooded hooks and capillaries from setiger 38-56. Anterior neurosetae all capillaries with inconspicuous sabre setae from setiger 3, not noticeably thicker than typical capillaries; bidentate hooded hooks from setiger 31-46, with earlier occurrence in smaller specimens. Pygidium with ventral cushion and low rounded dorsal lobe with single low lateral lobe on each side.

Comments: Our material agrees closely with the original description of Blake & Kudenov (1978). Variations in distribution of hooded hooks and bilobed neuropodial lamellae are greater than previously recorded. This is the first record of the species from South Australia.

Australian distribution: W.A. (Safety Bay*), S.A. (Venus Bay*, Elliston*, Sellicks Beach*, Kangaroo Isl.), Vic. (Port Phillip Bay, Westernport Bay), N.S.W. (Belmont Beach), Qld (Moreton Bay).

Habitat: Mud and sand flats.

***Scolecopsis (Neritides) edmondsi* n.sp.**

FIG. 2a-e.

Holotype: South Australia, 09C (W.19394).

Paratypes: 09C, 2 (AHP POLY 1384), 09C, 2 (USNM 074900), 09C, 2 (BMNH ZB 1982: 77-78), 09C, 6 (W.19395), 23B 1 (W.19396).

Description: Holotype, 25 mm long, 1 mm wide for 98 setigers. Paratypes range in size from 12-14 mm long, 0.8-1 mm wide for 60-65 setigers. All type material posteriorly incomplete. Prostomium acutely pointed, with 2 pairs small eyes; inner pair elliptical hidden by raised elevated caruncle attached to dorsum; caruncle with pronounced dorsal swelling; occipital tentacle absent. Peristomium forming ventral ruffle around prostomium; palps with swollen palpostyle, extending posteriorly to setigers 6-7. Setiger 1 with digitiform notopodial lobe and small globular neuropodial lobe; noto- and neurosetae present (Fig. 2a). Branchiae present from setiger 2, attached to notopodial lamellae basally, with free portion of branchia same length

as lamella; branchiae with very prominent blood vessel running along anterior margin; branchiae increasing in size posteriorly, rapidly becoming much longer than the notopodial lamellae. Notopodial lamellae elongating over sequential anterior setigers (Fig. 2b) forming narrow rectangular lobe, with development of interramal cirri (Fig. 2c); in middle and posterior setigers notopodial lamellae reduced to form elongated triangular lobe and by setiger 55 (Fig. 2d), becoming bilobed in far posterior setigers. Interamal cirri from setiger 31, becoming triangular in shape and greater in size than neuropodial lamellae, continuing on all subsequent setigers. Neuropodial lamellae initially semi-circular, gradually becoming more elongate; then dividing by setiger 29 to form interamal cirrus; ventral lobe and interamal cirrus initially equal triangular lobes, interamal cirrus subsequently becoming larger; in far posterior segments neuropodial lobe displaced ventrally but remaining undivided. Large intersegmental oval glandular creamy white patches present between neuropodia and interamal cirri. Well developed dorsal ridges present from setiger 2 to end of fragment, low in height.

Notosetae all capillaries, with most elongate setae from setiger 55; as none of the material examined is complete, the apparent lack of notopodial hooded hooks cannot be confirmed, if they occur it is later than setiger 98. Neurosetae initially capillaries; tridentate hooded hooks from setiger 43 mostly replacing capillaries neurosetae dominated by hooks and 1/2 capillaries. Hooded hooks tridentate with pair of stout denticles surmounting main fang (Fig. 2e).

Comments: *Scolecopsis edmondsi* n.sp. belongs to the sub-genus *Nerine* according to Pettibone (1963). Pettibone described all the species which she placed in the sub-genus and *S. edmondsi* n.sp. can be distinguished from all these species by the presence of notosetae on setiger 1 and the commencement of tridentate neurosetal hooks on setiger 36-44. Since that revision occurred several additional species have been described from Australia. *Scolecopsis* (*N.*) *vexillatus* (Hutchings & Rainer, 1979) which is characterised by posterior segments with a lamellar extension of the branchiae. Blake & Kudenov (1978) described *S. (N.) towra*, *S. (N.) pectinisetia* and *S. (N.) victoriensis* from S.E. Australia, two of these lack notosetae on setiger 1, and all have



Fig. 2. *Scolecopsis* (*N.*) *edmondsi* n.sp. a. anterior end, dorsal view. b. anterior view of the parapodium. c. anterior view of 40th parapodium. d. posterior view of 60th parapodium. e. neuropodial hooded hook. Scales in mm.

hooks beginning very much earlier than in *S. (N.) edmondsi* n.sp.

Etymology: This species is named after Dr Stan Edmonds who helped and largely made possible the field trip undertaken by one of the authors (PAH) during which the material forming the basis of this paper was collected.

Australian distribution: S.A. (Elliston, Snellings Beach).

Habitat: Encrusting algae and algal holdfasts.

Aonides Claparède (after Pettibone)

Prostomium acutely conical; peristomium more or less fused with prostomium. Branchiae from setiger 2, confined to anterior region of body, not fused to dorsal lamellae. Hooded hooks bi- or tridentate, in both noto- and neuropodia. Pygidium with anal cirri.

Type species *Nerine oxycephala* Sars

Aonides oxycephala (Sars)

Nerine oxycephala Sars, 1862: 64.

Aonides oxycephala. — Poore et al., 1975: 30.

— Ramos, 1976: 11-20, text-figs 1-2 (for synonymy). — Blake & Kudenov, 1978: 189-191.

Material examined: S.A. 19E, 1 (W.19314).

Description: A single specimen incomplete with 66 setigers, measuring 11.0 mm long, 0.7 mm wide. Prostomium conical, with occipital tentacle present, caruncle absent. Eyes not visible. Setiger 1 with noto- and neuropodial lamellae reduced, noto- and neurosetae present. Branchiae stout, cirriform, on setigers 2–18. Postsetal notopodial lamellae dorsally elevated and pointed in anterior setigers, becoming rounded posteriorly, postsetal neuropodial lamellae small, roughly triangular. All anterior setae capillaries; bidentate hooded hooks in notopodia from setiger 22–24; in neuropodia from setiger 22; posterior neuropodia with ventrally reflexed capillaries which gradually become stouter posteriorly and resemble sabre setae.

Comments: The number of branchiae and setigers on which noto- and neuropodial hooded hooks appear in our specimen are well within the wide ranges given by Ramos (1976) for this species, and other characteristics are in close agreement. First record from South Australia.

Australian distribution: S.A. (Emu Bay, Kangaroo Island*), Vic. (Port Phillip Bay), N.S.W. (Merimbula, Jervis Bay*, Port Hacking*, Botany Bay*).

Habitat: *Posidonia* seagrass beds.

Aquilaspio Foster

Prostomium subtriangular; with anterior border rounded or sometimes extending slightly laterally, continuing posteriorly as more or less developed posterior keel or caruncle. Peristomium surrounding prostomium as hood, developed to varying degrees. Branchiae, two to four pairs all pinnate, from setiger 2. Anterior setae all capillaries; tridentate or multidentate hooded hooks present in posterior setigers of neuro- and notopodia. Pygidium with anal cirri.

Type species *Prionospio sexoculata* Augener

Aquilaspio aucklandica (Augener)

Prionospio aucklandica Augener, 1924: 69–70, text-fig. 24, 1926: 158–159, fig. 1.

Aquilaspio aucklandica, Foster, 1971: 105–106, Hutchings and Ruiter, 1979: 763.

Prionospio (*Aquilaspio*) *aucklandica*, Blake & Kudenov, 1978: 221–222, text-fig. 25b–g.

Material examined: S.A. 61A, 2 (W.19318), 12C, 5, (W.19315), 16C, 61 (W.19320), 19A, 1

(W.19317), 19E, 3 (W.19316), 33B, 21 (W.19319).

Description: Size range: 6.5–26 mm long, 0.4–0.8 mm wide for 50–113 setigers; anterior fragments of larger specimens present up to 1.1 mm width. Prostomium anteriorly rounded with minor irregularities; caruncle high, keel-like, extending to posterior margin of setiger 1. Peristomium dorsally fused to setiger 1, forming low lateral wings about prostomium at base of caruncle; palps thick, crenulate, extending to setiger 9–15. Branchiae 3 pairs, on setigers 2–4; each pair densely pinnate, similar in length in large specimens, but subsequent pairs decreasing in length in small specimens with pinnules becoming sparse and fewer, occasionally disappearing by third pair. Setiger 1 with reduced rounded noto- and neuropodial lamellae; notosetae lacking. Notopodial lamellae becoming larger, elongated dorsally pointed and medially curved over setigers 2–4, then becoming rounded and decreasing in size posteriorly. Neuropodial lamellae similar throughout in size to notopodia; generally rounded in shape except sharp triangular ventrally directed projection in setiger 2. Anterior setae in both noto- and neuropodia all capillaries, sheathed, distally granular, becoming finer posteriorly; hooded hooks from setiger 25–33 in notopodia, 15–18 in neuropodia with about 5 tiers of apical teeth above main tang, primary hood inflated, secondary hood distinct; ventral sabre setae in neuropodia from setiger 10–11, each stout, sheathed, distally granular, tapering abruptly to filamentous tip; smaller individuals with sabre setae from setiger 10 and hooded hooks in the notopodia from setiger 25 and in the neuropodia from setiger 15. Pygidium with long cirrus dorsomedially and 2 stout papillae.

Comments: Size-dependent variations in branchiae and setal patterns have not been noted previously. Blake & Kudenov (1978, p. 222), state that a low dorsal crest is present on setiger 7. This was not indicated by Augener (1924) and was not observed on our material, although the anterior margins of post-branchial setigers were slightly raised to form low dorsal ridges. This is the first record of this species from South Australia.

Australian distribution: S.A. (Port Augusta*, Torrens Island*, Sellicks Beach*, Emu Bay*, Cape Donby*), Vic. (Port Phillip Bay, Westernport Bay), N.S.W. (Merimbula, Botany Bay, Careel Bay*, Wallis Lake).

Habitat: Intertidal and sub-tidal sediments including seagrass beds, among coralline algae.

Aquilaspio multipinnulata (Blake & Kudenov)
new comb.

Prionospio (*Aquilaspio*) *multipinnulata* Blake & Kudenov, 1978: 219–221, text-fig. 24a–f.

Material examined: S.A. 04B, 2 (W.19324), 07B 1 (W.19321), 11A, 6 (W.19329), 12B, 1 (W.19326), 13A, 4 (W.19330), 19D, 5 (W.19327), 19E, 1 (W.19323), 21B, 1 (W.19328), 22A, 2 (W.19322), 27C, 12 (W.19325), Onkaparinga Estuary, 1 (W.6071) coll. Shepherd, N.S.W., Merimbula (W.11736), identified by Blake & Kudenov.

Description: A single entire specimen (W.19326) measures 54 mm long, 1.6 mm wide for 137 setigers; posteriorly incomplete specimens of 0.9–1.8 mm width. Prostomium broadly rounded anteriorly with high, keel-like caruncle extending to posterior margin of setiger 1; two-three pairs of eyes present. Petiole dorsally fused to setiger 1, together with notopodial lamella forming low but distinct lateral wings surrounding prostomium. Four pairs of densely pinnate branchiae from setiger 2. Setiger 1 with notosetae reduced to small bundle at base of notopodial lamella, neurosetae normal in size. Notopodial lamellae becoming more elongate dorsally, pointed and medially hooked over setigers 1–4 then becoming rounded, laterally directed, decreasing in size posteriorly; in some anterior setigers notopodial lamellae extending across dorsum to form very low, rounded, barely-raised dorsal ridges from about setiger 10, occasionally absent. Neuropodial lamellae showing similar to notopodial size variations, generally rounded throughout except for sharp ventrally directed triangular projection in setiger 2 and laterally pointed lamellae in setiger 3. Anterior noto- and neurosetae all capillaries, sheathed, distally granular, becoming finer with less distinct sheaths posteriorly; hooded hooks from setiger 26–39 in notopodia, 20–24 in neuropodia, hooks with 4–5 tiers of apical teeth above main fang, secondary hood distinct; one, or rarely 2 ventral sabre setae in neuropodia from setiger 10–11, each sheathed in anterior setigers, distally granular, tapering rapidly to filamentous tip. Pygidium with long dorso-medial cirrus and a pair of stout lateral papillae.

Comments: Our material agrees closely with the description of Blake & Kudenov (1978) except for fewer pairs of eyes and slightly more

posterior appearance of neuropodial hooded hooks. Variability in the setiger at which types of setae first appear was not recorded by Blake & Kudenov. The pygidium and the occasional, variable presence of low dorsal crests have not been described previously. This is the first record of the species from South Australia.

Australian distribution: S.A. (widespread*), Vic. (Port Phillip Bay), N.S.W. (Merimbula, Wagonga R.*).

Habitat: Among seagrasses and algae, in mud, under rocks.

Aquilaspio pyramidalis n.sp.

FIG. 3a–c.

Holotype: South Australia, 20A (W.194024).

Paratypes: 04A, 16 (W.194026), 04A, 1 (W.194025), 07A, 9 (W.194029), 07B, 31 (W.194030), 08A, 14 (USNM 074898), 18A, 12 (AHF POLY 1382), 18B, 10 (RMNH ZB. 1982.66–75), 19A, 23 (W.194031), 20A, 2 (W.194027), 21A, 28 (W.194028), 27B, 4 (W.194032), 33B, 2 (W.194033).

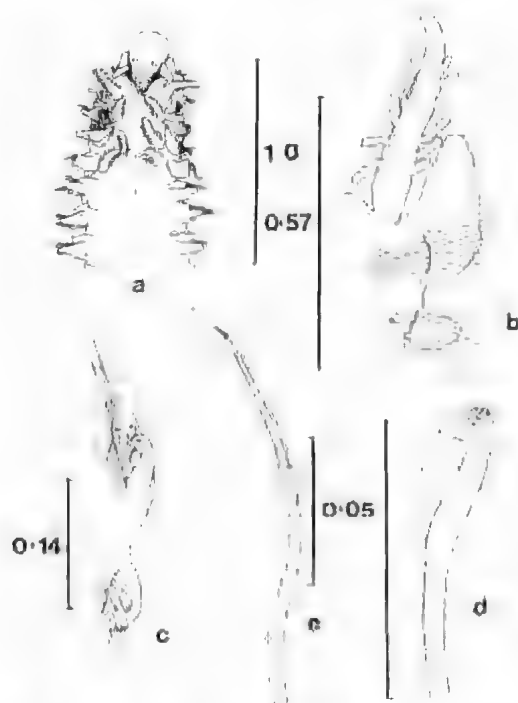


Fig. 3. *Aquilaspio pyramidalis* n.sp. a. anterior end, dorsal view (Paratype W.194026). b. anterior view of 4th parapodium. c. anterior view of 52nd parapodium. d. notopodial hooded hook from 52nd parapodium. e. sabre seta. Scales in mm.

Description: Holotype, 10 mm long, 0.7 mm wide for 71 setigers. Paratypes range in size from 24 setigers, 2.0 mm length, 0.25 mm width to 81 setigers, 18.5 mm length, 0.85 mm width. Prostomium broadly rounded anteriorly with low, thick caruncle extending to posterior margin of setiger 1; two pairs of eyes arranged in oblique line on either side. Peristomium fused with notopodial lamellae of setiger 1 to form high lateral wings about posterior margins of prostomium and base of caruncle, extending anteriorly as low lateral wings close to sides of prostomium (Fig. 3a); palps lost. Four pairs of sparsely pinnate branchiae on setigers 2-5, becoming shorter posteriorly with few pinnules. Postsetal notopodial lamellae well-developed and rounded in setiger 1, increasing in size and becoming more dorsally elongate, pointed and medially hooked up to setiger 4 then becoming rounded, laterally directed, decreasing in size posteriorly, terminating laterally on dorsum and not extending to form dorsal crests (Fig. 3b). Neuropodium of setiger 1 inflated, pyramidal in form with postsetal lamellae barely developed as small ridge on apex; subsequent neuropodia normal; anterior setigers with well-developed postsetal lamellae showing similar variation in size to notopodial lamellae; all rounded except bluntly triangular dorsally in setigers 2 and 3. Postsetal lamellae of both noto- and neuropodia reduced to low, thick ridges, in those setigers bearing hooded hooks, with hooks often partly surrounded by folds in body wall (Fig. 3c). Presetal lamellae present anteriorly in both noto- and neuropodia as low ridges. Anterior noto- and neurosetae all capillaries arranged in narrow bundles in setiger 1, thereafter capillaries in 2 broad, disorganised, partially separated groups in both noto- and neuropodia reduced to single fascicle by middle setigers and 1 or 2 setae posteriorly; capillaries of anterior setigers stout, sheathed, distally granular, frequently appearing unilimbate, becoming slender posteriorly with inconspicuous sheaths; 0-3 hooded hooks from setiger 26 (left)-27 (right) in notopodia, 0-5 from setiger 11 in neuropodia, with apical teeth in 5-6 tiers above main tang, two teeth per tier, primary hood broadly inflated, secondary hood not visible (Fig. 3d); single ventral sabre seta present in each neuropodium, from setiger 12, each stout, densely granular distally, tapering rapidly to filamentous tip, sheath well developed anteriorly

but diminishing posteriorly (Fig. 3e). Pygidium with a single, long dorsomedial cirrus and 2 stout lateral papillae. Coelom loosely packed with eggs of about 70 μ m diameter. The paratype material exhibits some variation from the holotype. Some have 4 pairs of eyes; palps stout extending to setiger 4-10. Number of branchiae becoming reduced in small specimens with a corresponding reduction in number of pinnules frequently to only 1, 2 or 0 in more posterior branchiae. Smallest specimen with only a single pair of branchiae on setiger 2 and completely lacking pinnules, suggesting that number of gills and pinnules increase with increasing size and presumably age. Notopodia with 0-2 hooded hooks from setiger 25-30 in most specimens increasing to as many as 5 posteriorly. Neuropodia with 0-5 hooded hooks generally from setiger 11, rarely from setiger 12. One or rarely 2 sabre setae generally from setiger 13, occasionally from setiger 11-16. Very small specimens with noto- and neuropodial hooded hooks and neuropodial sabre setae from as early as setiger 18, 8 and 10 respectively. The smallest specimens can only be assigned to *A. pyramidalis* n.sp. because of the wide range of sized material available and this permits the sequential development of features to be followed with increasing size.

Discussion: *Aquilaspio pyramidalis* n.sp. is similar to *A. multipinnulata* (Blake & Kudenov, 1978), *A. parvona* (Hartmann-Schröder, 1962), *A. tenuis* (Verrill, 1880), *A. tetelensis* (Gibbs, 1971) and *A. treadwelli* (Hartman, 1951) in possessing four pairs of pinnate branchiae on setigers 2-5. It may be distinguished from all of these species by the setigers on which neuropodial hooded hooks and sabre setae first appear and by the form of the neuropodium of setiger 1.

Etymology: the specific name refers to the form of the neuropodium of setiger 1.

Australian distribution: South Australia (widespread).

Habitat: Intertidally among algae, seagrasses and under rocks, subtidally among rocks and sponges.

Minuspia Foster

Prostomium subtriangular, anteriorly rounded, blunt or inflated, extending posteriorly as a more or less well-developed caruncle. Peristomium forming a hood surrounding prostomium, variously developed.

Branchiae all cirriform, from setiger 2, varying from 4–40 pairs. Anterior setae all capillaries. Hooded hooks in posterior noto- and neuropodia, bidentate to multidentate. Pygidium with anal cirri.

Type species *Prionospio cirrifera* Wirén

Minuspio cirrifera Wirén

Prionospio (?) *cirrifera* Wirén, 1883: 409.

Minuspio cirrifera, Foster, 1971: 108–112, figs 262–275 (for synonymy).

Prionospio (*Minuspio*) *cirrifera*, Blake & Kudenov, 1978: 222–224, text-fig. 25a (for synonymy).

Material examined: S.A., 02B, 1 (W.19302).

Description: Posteriorly incomplete specimen of 61 setigers, measuring 15 mm long, 0.6 mm wide. Prostomium bluntly rounded, caruncle extending to posterior margin of setiger 1. Peristomium forming low lateral wings partly enclosing prostomium; palps slender, extending to setiger 8. Ten pairs of branchiae from setiger 2, all long, cirriform. Setiger 1 reduced with postsetal notopodial lamella larger than neuropodial but both small, noto- and neurosetae present. Postsetal notopodial lamellae increasing in size and becoming more dorsally pointed to setiger 8 then gradually, becoming smaller, rounder, more laterally directed, forming low dorsal crests from setiger 12, decreasing posteriorly to setiger 20 then absent. Postsetal neuropodial lamellae small, rounded lateral flaps, with those of setigers 2–3 having slightly dorsal point. Presetal lamellae smaller, rounded. Anterior setae all sheathed distally granular capillaries; setae becoming finer posteriorly. Hooded hooks from setiger 49 in notopodia, 19 in neuropodia, with apical teeth arranged in 3–4 tiers above main fang; secondary hood distinct. A single sabre setae in neuropodium from setiger 16.

Comments: Foster (1971, p. 110) states that if the hooded hooks of *M. cirrifera* have a secondary hood, then "it is extremely closely applied to the hook and is barely distinguishable (fig. 273)". The hook is illustrated as having a secondary hood which is quite distinct below the main fang: a condition identical to that in our specimen. Notopodial hooded hooks appear slightly later in our specimen than indicated by Foster (1971) and Blake & Kudenov (1978) and the caruncle is slightly shorter than described by the latter authors. None of these authors indicate the presence of sabre setae in their texts, although

they are illustrated by Foster (1971, fig. 269). Otherwise our specimen is in close agreement with both descriptions. This is the first record of the species from South Australia.

Australian distribution: S.A. (Streaky Bay*), Vic. (Port Phillip Bay, Gippsland Lakes), N.S.W. (widespread), Qld (Deception Bay)

Habitat: Seagrass beds, mud, sand.

Prionospio Malmgren

Prostomium, with anterior margin incised or rounded, without frontal horns, caruncle variously developed. Peristomium fused in varying amounts with setiger 1 often forming low lateral wings. Setiger 1 with reduced parapodia, notopodia on branchiferous segments enlarged, post-branchial notopodia becoming smaller, inconspicuous dorsal folds or crests present or absent on postbranchial segments rarely on branchiferous segments. Branchiae cirriform and pinnate, limited to anterior setigers. Anterior setae all capillaries, hooded hooks in posterior noto- and neuropodia; hooks, bi, tri or multidentate, inferior sabre setae present. Pygidium with 1 long medial cirrus and 2 short ventrolateral cirri or thickened lobes.

Type species *Prionospio steenstrupi* Malmgren.

Prionospio multicristata Hutchings & Rainer

Prionospio multicristata Hutchings & Rainer, 1979: 768–771, text, fig. 5a–i.

Material examined: S.A., 02B, 1 (W.194023), 11A, 1 (W.194022), 13A, 2 (W.194021), N.S.W., Careel Bay, *Posidonia* (Holotype W.8286).

Description: A single entire specimen (W. 194021) of 77 setigers measures 12.5 mm long, 0.75 mm wide; posteriorly incomplete specimens of 0.5–1.6 mm wide. Prostomium broadly rounded anteriorly, tapering rapidly to narrow caruncle extending to posterior margin of setiger 4. Two pairs of eyes, anterior pair small lateral; posterior pair larger, comma shaped. Peristomium forming low-lateral wings close about prostomium. Four pairs of branchiae, on setigers 2–5. First and fourth pairs long, thick, densely pinnate over basal 2/3, distally bare; second and third pairs short, stout, cirriform. Setiger 1 with notopodial and neuropodial lamellae slightly reduced, both noto- and neurosetae present. Notopodial lamellae becoming larger and more dorsally pointed on setigers 2–6, then rounded and decreasing gradually in size posteriorly; each pair joined across dorsum in form high

crest from setiger 7, decreasing posteriorly to become medially separated at setiger 24–31, then absent. Neuropodial lamellae showing similar variation in size to notopodial, rounded except with sharp triangular downwards projection in setiger 2. Anterior noto- and neurosetae all sheathed; capillaries, densely granular distally, in one specimen (W.194022) sheaths of many anterior capillaries also densely granular, intensely gold in colour; capillaries becoming more slender with sheaths reduced posteriorly. Hooded hooks from setiger 27–31 in notopodia, 14–18 in neuropodia with 4–5 tiers of apical teeth above main fang, secondary hood distinct. One or rarely 2 ventral sabre setae in neuropodia from setiger 10, each stout, sheathed, distally granular, tapering abruptly to filamentous tip. Pygidium with long, filiform cirrus dorsomedially and two stout lateral papillae.

Comments: The only substantial difference between our material and that of Hutchings & Rainer (1979) is the earlier appearance of notopodial hooks. This is probably due to the smaller size of our specimens. The pygidium of one specimen was intact and there was some variability in the setiger at which hooded hooks first appeared. Neither of these features have been described previously. This is the first record of the species from South Australia.

Australian distribution: W.A. (Cervantes*); S.A. (Sireaky Bay*, Port Lincoln*); N.S.W. (Merimbula*, Port Hacking*, Carcel Bay), Qld (Calliope R.*).

Habitat: Sand, seagrass beds.

Spio Fabricius

Prostomium anteriorly rounded or incised, frontal horns lacking; eyes present or absent. Branchiae from setiger 1 continuing throughout body, sometimes partially fused to dorsal lamellae in anterior setigers, free posteriorly. Noto- and neurosetae all capillaries, neurosetae including capillaries, hooded hooks and sabre setae. Pygidium with anal cirri.

Type species *Nereis filicornis* Müller.

Spio tridentata n.sp.

FIG. 4a–d

Holotype: South Australia, 21B, (W.194019).

Other material examined: *Spio pacifica* N.S.W., Towra Point, Botany Bay, St 329 *Halophila*, 13 *Paratypes* (W.13029) coll. N.S.W. State Fisheries, J. H. Blake & K. K. Klenner.

Description: Body robust, broadly rectangular in cross-section. Colour pink. Posteriorly incomplete fragment of 57 setigers, 18 mm long and 1.9 mm wide at setiger 25. Prostomium broad, blunt, anterior margin almost truncate with faint medial indentation; without lateral wings; eyes not visible, caruncle broad, posteriorly rounded, extending to posterior margin of setiger 1 (Fig. 4a). Nuchal organs not visible, but tissue damaged in that region. Peristomium broad, not forming lateral wings about prostomium. Branchiae thick, cirriform, distally rounded, well developed on setiger 1, increasing gradually in size over first few setigers to attain a twice initial length by setiger 6–8 (Fig. 4b) then decreasing slightly over remaining setigers (Fig. 4c). Setiger 1 with noto- and neuropodial setae and lamellae. Subsequent parapodial lamellae all thick, inflated. Postsetal notopodial lamellae rounded, extending dorsally and fused, except for small dorsal extremity, to lateral margins of branchiae, increasing in size over first few setigers; presetal notopodial lamellae low, rounded, much smaller than postsetal lamellae anteriorly, becoming larger posteriorly but not extending more than half way to edge of postsetal lamellae. Postsetal neuropodial lamellae semicircular in profile and initially smaller than notopodial, attaining similar size by setiger 15–16 then increasing further to become somewhat larger posteriorly; presetal neuropodial lamellae low, rounded, much smaller than postsetal in anterior then enlarging laterally to reach almost as far as postsetal in posterior setigers. Noto- and neurosetae all capillaries, anteriorly arranged in two broad, parallel rows with a smaller third group dorso-posteriorly. The two major rows then coalescing in middle setigers and remaining as single row posteriorly. Anterior neurosetae all capillaries in two broad rows, posterior row replaced from setiger 28 (left)–29 (right) by a single, similarly broad row of 6–11 hooded hooks with an additional, ventrally-reflexed group of 4–5 sabre setae. All capillaries sheathed, those in the anterior of the two major rows of both parapodial rami with shafts distally granular, those in posterior rows non-granular; capillary sheaths never granular; with dorsal granular capillaries in both parapodial rami frequently appearing unilimbate. Neuropodial hooded hooks tridentate with large, pointed main fang surmounted by 2 stout apical teeth decreasing successively in size (Fig. 4d). Pri-

mary hood granular, completely enclosing teeth fine but clearly visible secondary hood. Sabre setae unilimbate with shafts finely granular distally, tapering gradually to a fine tip. Pygidium and posterior setigers lost.

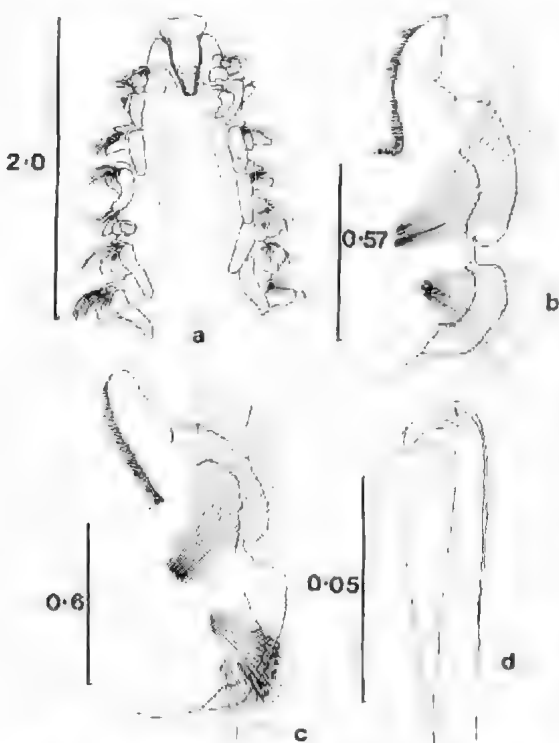


Fig. 4. *Spio tridentata* n.sp. a. anterior end, dorsal view. b. anterior view of 6th parapodium. c. anterior view of 30th parapodium. d. hooded hook.

Comments: *Spio tridentata* n.sp. is similar to *S. cirrifera* (Ranse & Hobson, 1968), *S. linticola* Verrill, 1880 (after Holmquist, 1967), *S. pacifica* Blake & Kudenov, 1978 and *S. pettiboneae* Foster, 1971 in possessing tridentate hooded hooks. It differs from all of these species in the much later appearance of the hooks and the almost complete fusion of branchiae and notopodial lamellae in at least anterior and middle setigers. Further differences include the conspicuous, triangular presetal notopodial lamellae of *S. pettiboneae*, the presetal notopodial cirrus in anterior setigers and the dorsally bilobed prostomium of *S. cirrifera* and the bilobed caruncle, partially hooded sabre setae and granular-sheathed capillaries of *S. pacifica*.

Etymology: the specific name refers to the tridentate hooded hooks.

Australian distribution: S.A. (Stokes Bay, Kangaroo Island).

Habitat: Under rocks at low tide level.

Microspio Mesnil (following Blake & Kudenov)

Prostomium anteriorly rounded to bilobed, without frontal horns; eyes present or absent; occipital tentacle present or absent. Branchiae from setiger 2, notosetae only capillary; neurosetae including capillaries, hooded hooks and sabre setae. Pygidium with anal cirri.

Type species *Spio mecznikowianus* Claparède.

Microspio granulata Blake & Kudenov

Microspio granulata Blake & Kudenov, 1978: 232, figs 30–31.

Material examined: S.A. 02A, 1 (W.19303). 03B, 13 (W.19306). 03C, 1 (W.19304). 03E, 8 (W.19305). 03F, 2 (W.19307).

Description: Size range of entire specimens of 27–40 setigers, 3.2–11 mm long, 0.5–1.1 mm wide; posteriorly incomplete specimens up to 1.6 mm wide. Prostomium bilobed, deeply incised; caruncle extending to setiger 2 with prominent pointed or rounded occipital papilla; high transverse ciliated ridge behind caruncle enclosed laterally and posteriorly by curved nuchal grooves; similar ridge on each succeeding setiger; two pairs of eyes in oblique series; palps stout, basally inflated, extending to setiger 10–14. Branchiae stout, cirriform, from setiger 2 to all but last few setigers. Setiger 1, reduced without notosetae, noto- and neuropodial lamellae small. Postsetal notopodial lamellae of most setigers small, rounded, dorsally directed; bluntly pointed dorsally in far anterior setigers; becoming elongate and tongue-like in far posterior setiger. Postsetal neuropodial lamellae small, rounded, decreasing posteriorly. Presetal lamellae in both rami smaller, low, rounded. Notoetae all capillaries. Neurosetae with capillaries anteriorly tridentate hooded hooks from setiger 9; a single sabre setae ventrally from setiger 14–17. Pygidium with 4 short, stout anal cirri dorsal pair slightly longer and more pointed than ventral pair.

Comments: Our material agrees closely with the description of Blake & Kudenov (1978). The pygidium and parapodial lamellae of far posterior setigers have not been previously

described. This is the first record outside the type locality.

Australian distribution: S.A. (Streaky Bay*), N.S.W. (Botany Bay).

Habitat: Among mussels, seagrasses, in sand.

Boccardia Carazzi, emended Blake & Kudenov

Prostomium rounded or divided, extending posteriorly as caruncle. Setiger 1 with or without notosetae. Setiger 5 modified with 2 types of major spines, companion setae absent. Bidentate hooded hooks from setigers 7–11. Posterior notopodial spines present or absent. Branchiae from setiger 2, absent setiger 5, present on following variable number of setigers. Pygidium disk like with or without separate lobes or reduced to small lobes or cuffs.

Comment: *Boccardia fleckera* n.sp. has hooded hooks from setiger 11. The generic definition is revised here to accommodate that species.

Type species *Polydora polybranchia* Haswell.

Boccardia chilensis Blake & Woodwick

Boccardia chilensis Blake & Woodwick 1971: 36.

Blake & Kudenov, 1978: 238–240, fig. 33d–e.

Material examined: S.A., 06A, many (W.19295). Coorong (W.19208) coll. M. Geddes.

Description: Prostomium deeply divided on anterior margin. Setiger 1 with long notosetae. Setiger 5 with spines of 2 types, simple falcate spines and spines with expanded concave cup containing bluntly conical tooth; bidentate hooded hooks from setiger 7. Branchiae from setiger 2. Pygidium a fleshy pad.

Comments: Our material agrees well with previous descriptions except that in the South Australian material, the occipital tentacle is absent. First record from South Australia.

Australian distribution: S.A. (Venus Bay*, Coorong*), W.A. (Bunbury, Leschenault Inlet*), Vic. (Port Phillip Bay). N.S.W. (widespread) and Macquarie Island.

Habitat: In amongst algal mat.

Boccardia fleckera n.sp.

FIG. 5a–f.

Holotype: South Australia 30D, 1 (W.194020).

Description: Posteriorly incomplete, 23 setigers measuring 4 mm long and 0.5 mm wide. Robust body, speckled with brown flecks of pigment, concentrated posteriorly on both ventral and dorsal surfaces. Prostomium deeply

incised, with 2 pairs of spherical eyes; caruncle present, extending to middle of setiger 2 with short occipital present. Palps with swollen bases, extending to setiger 10 (Fig. 5a). Setiger 1 with large prominent notopodial lamellae and notosetae; subsequent parapodia with blunt triangular notopodial lobe, and larger truncate triangular neuropodial lobe (Fig. 5b–c). Branchiae, stumpy, stout from setiger 2–4 and 6 onwards, attached to base of notopodial lobe, but longer than parapodial lobes.

Setiger 5 heavily modified, notopodial lamellae absent, small globular neuropodial lobe, with 5 worn brush tipped setae (Fig. 5e) and 3 curved falcate smooth spines (Fig. 5f), neurosetal capillaries present. Neurosetae anteriorly long thin narrow bladed capillaries, from setiger 11, one to two hooded strongly bidentate hooks (Fig. 5d) present and by setiger 13, hooks predominate. Notoetae all capillaries at least to setiger 23.

Comments: *Boccardia fleckera* n.sp. has been placed within the genus *Boccardia* even though it does not strictly agree with Blake & Kudenov's emended generic description in that the neuropodial hooded hooks begin on setiger 11 and not on setiger 7–8. Rainer (1973) erected the genus *Paraboccardia* for species with hooks commencing on setiger 8 which Read (1975) reduced to a subgenus. This was accepted by Blake & Kudenov (1978). Woodwick (1964) erected another genus in this complex *Tripolydora*, for species with hooks commencing on setiger 9. Blake & Woodwick (1981) have recently suggested that this genus is more closely related to the *Polydora* complex than to *Boccardia*. As we have only a single specimen we have decided to describe it as a new species within the genus *Boccardia*, as it clearly belongs to this complex from the modification of setiger 5 and the type of setae present.

Etymology: the specific name *fleckera* refers to the pigmentation pattern on the body.

Australian distribution: S.A. (Cape du Couedic, Kangaroo Island).

Habitat: Exposed algal holdfasts.

Boccardia proboscidea Hartman

Boccardia proboscidea Hartman 1940: 382

Blake & Kudenov, 1978: 238; fig. 33a &

Material examined: S.A., 09A (W.19297) 1901 (W.19296), many individuals at both sites.

Description: Prostomium rounded on anterior margin; caruncle extending to end of setiger 3,

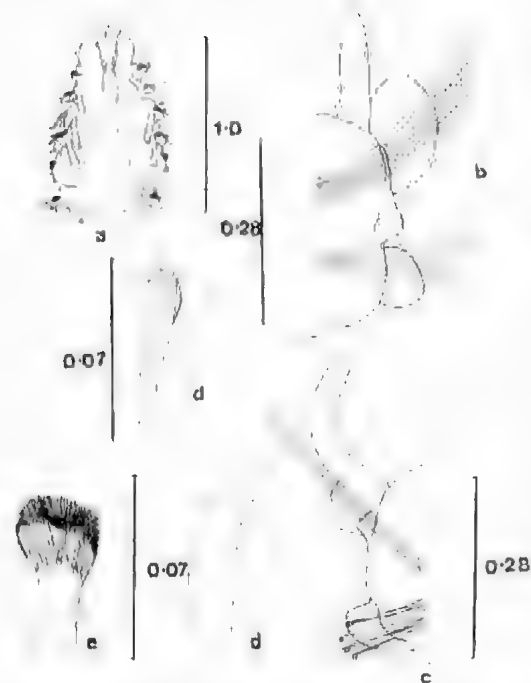


Fig. 5. *Boccardia fleckera* n.sp. a. anterior end, dorsal view. b. anterior view of 4th parapodium. c. anterior view of 15th parapodium. d. neurosetal hook. e-f. modified setae of setiger 5. Scales in mm.

with two pairs of eyes. Branchiae from setiger 2, absent from posterior third of body. Setiger 5 with two types of setae: one type simple, falcate, weakly hooked with blunt tips, second type with broad asymmetrical flattened head, slightly domed, densely bristled distally. Bidentate hooded hooks from setiger 7.

Comments: Our material agrees with the description of Blake & Kudenov (1978) who first reported this species from Australia in Port Phillip Bay, Victoria, the first record from the southern hemisphere. First record from South Australia.

Australian distribution: W.A. (Fremantle*), S.A. (Elliston*), Vic. (Port Phillip Bay).

Habitat: In amongst encrusting algae or *Galerula* worm tubes.

Polydora Bosc, emended Blake & Kudenov

Prostomium entire or divided, extending posteriorly as caruncle; eyes present or absent. Setiger 1 with or without notosetae. Setiger 5 greatly modified with major spines of one kind usually with slender companion setae, spines arranged in a singled curved row. Posterior notopodial spines sometimes present. Neuro-

podial hooded hooks bidentate beginning on setigers 7-17. Branchiae commencing posteriorly to setiger 5. Pygidium variable, reduced or enlarged, cuff-like, saucer-like or lobate.

Type species *Polydora cornuta* Bosc.

Polydora hoplura Claparède

Polydora hoplura Claparède, 1870: 58. Read, 1975: 411. Blake & Kudenov, 1978: 264, fig. 47.

Material examined: S.A. 17 (W.19298).

Description: Large species up to 40 mm in length for over 160 segments. Prostomium weakly incised, with caruncle extending to end of setiger 3, bearing low occipital tentacle. Setiger 1 with neurosetae; notosetae absent. Modified setae, setiger 5 blunt to pointed with subterminally lateral flange present, frequently resembling a tooth; companion setae bilimbate. Hooded hooks from setiger 7 with constricted shaft. Far posterior segments with large recurved dorsal spines directed toward midline of body. Branchiae from setiger 7, continuing along body until spine bearing region. Pygidium broad, flat, with deep ventral notch.

Comments: This species has been previously reported as forming mud blisters on oysters. In South Australia the species occurred amongst encrusting fauna on jetty piles. This is the first record from South Australia.

Australian distribution: S.A. (Rapid Bay*), Tas. (Simmons Beach), Vic. (Port Henry Pier, Corio Bay, Port Phillip Bay).

Habitat: In amongst sessile organisms on jetty piles.

Polydora ligni Webster

Polydora ligni Webster, 1879: 119. See Blake, 1971 and Foster, 1971 for synonymy.

Material examined: S.A. 12B, 5 (W.19299).

Description: Large specimen up to 32 mm length for 80 setigers. Prostomium bluntly bilobed with occipital tentacle. Two pairs of eyes. Setiger 1 without notosetae, digitiform notopodial lobe. Setiger 5, simple falcate major spines with blunt subdistal tooth; companion setae delicate, feathery; dorsal and ventral capillaries absent. Hooded hooks with constriction on shaft from setiger 7. Posterior modified setae absent. Branchiae from setiger 7.

Comments: First record from South Australia.

Australian distribution: S.A. (Torrens Island*), Vic. (Port Phillip Bay)

Habitat: Intertidal mudflats.

Polydora socialis (Schmarda)

Polydora socialis. Blake, 1971: 20-23, figs 13-14, 1979: 607-609 (synonymy); Blake & Kudenov, 1978: 248-250, fig. 38d-e.

Material examined: S.A. 02A, 5 (W. 19300), 02C, 2 (W.19301).

Description: Moderately sized individual up to 9 mm long and 0.75 mm wide for 55 setigers. Prostomium deeply incised, caruncle extending to setiger 4-5; occipital tentacle absent; with two pairs of eyes. Setiger 1 with notosetae. Major spines of setiger 5 simple, falcate with subterminal swelling. Neuropodial hooded hooks from setiger 7, without constriction on shaft. Modified posterior setae absent. Branchiae from setiger 8. Gizzard externally shown by dorsal swelling on setigers 18-19.

Comments: First record from South Australia. *Australian distribution*: S.A. (Streaky Bay*), Vic. (Port Phillip Bay). N.S.W. (Botany Bay, Sydney Harbour).

Habitat: On mud flats, associated with clumps of mussels or *Posidonia* seagrass.

Pseudopolydora Czerniavsky emended
Blake & Kudenov

Prostomium entire or divided, extending posteriorly as caruncle, occipital tentacle present or absent. Eyes present or absent. Setiger 1 usually reduced, with or without notosetae (and in some species without neurosetae if animals are reproducing asexually or regenerating). Setiger 5 not greatly modified with noto- and neuropodia often well developed bearing postsetal lobes, and spreading fascicles of capillaries, with curved row of heavy modified spines of 2 types or single type with companion setae; modified setae often arranged in J or U shaped setal group. Posterior notopodial spines sometimes present. Neuropodial hooded bidentate hooks from setiger 8. Branchiae present posteriorly to setiger 5. Pygidium variable, enlarged or reduced, collar like or divided into lobes or small lappets.

Type species *Pseudopolydora antennata* (Claparède).

Pseudopolydora antennata Claparède
FIG. 6a-c.

Polydora (*Pseudopolydora*) *antennata*. Hartmann-Schröder, 1981: 50, figs 115-118.

Material examined: S.A. 16A, 1 (W.19386), 18A, 3 (W.19385), 20A, 6 (W.19387), 21A, 3 (W.19388), 27A, 1 (W.19384), N.S.W., Merim-bula (W.11703), Qld. Moreton Bay, Jackson

Creek (W.6042), Serpentine Creek (W.6043), Brisbane R. (W.7474).

Description: Colourless. Length up to 25 mm for 45 setigers, some complete individuals. Prostomium deeply incised, with lobes widely flaring. Occipital tentacle pointed erect, caruncle extending to middle of setiger 6. Two pairs of distinct eyes. Setiger 1 with small rounded notopodial lobe, notosetae absent (Fig. 6a). Setiger 5 poorly modified with 2 types of setae, arranged in J shaped row, outer row consisting of pennoned setae (Fig. 6b), (short spoon-like tips to blades) and inner row of simple spines, slightly curved apically and tips finely hirsute (Fig. 6c). Hooded bidentate neuropodial hooks from setiger 8, although in one specimen 2 hooks present on setiger 7, hooks immediately replace neurosetal capillaries. Branchiae present from setigers 7-22. Pygidium 2 semicircular valves.

Comments: This is the first record of this species from southern Australia, although Hartmann-Schröder has recently described it from Geraldton in Western Australia.

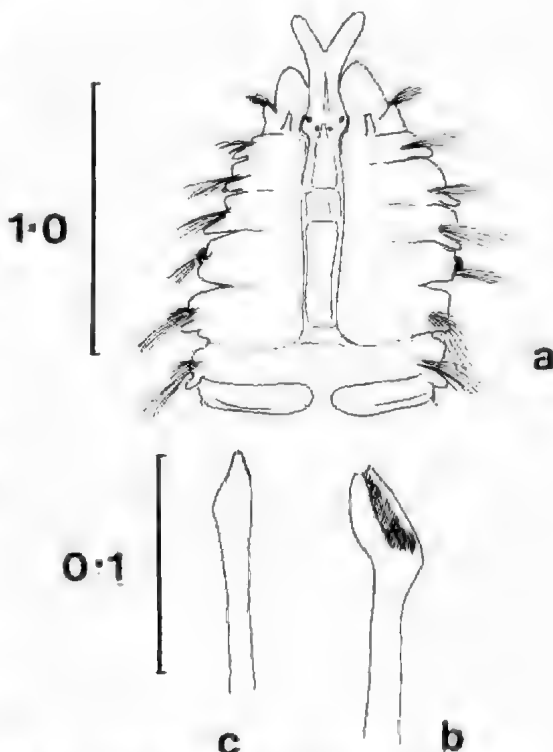


Fig. 6. *Pseudopolydora antennata* a, anterior view, dorsal view (W.19385), b-c, modified setae of setiger 5. Scales in mm.

Australian distribution: W.A. (Geraldton*), S.A. (Sellick's Beach, Victor Harbor, Kangaroo Island).

Habitat: Crevice fauna often associated with tufted algae.

Pseudopolydora paucibranchiata (Okuda)

FIG. 7a-e.

Polydora (Carazzia) *paucibranchiata* Okuda, 1937: 231-233, figs 11-12.

Pseudopolydora paucibranchiata. Blake & Kudenov, 1978: 268.

Pseudopolydora kempfi. Hutchings & Rainer, 1979: 773-774. Not Southern.

Material examined: S.A. 11A, 1 (W.19393). 12A, 14 (W.19389, 19390). 12B, 1 (W.19391). 12C, 2 (W.19392). N.S.W. Botany Bay, Towra Beach (W.13045), Kurnell (W.17427). Jervis Bay (W.5223). Vic. Port Phillip Bay (NMV G3177, 3178, 3180), Hobsons Bay, Yarra River (NMV G3183), identified Blake & Kudenov.

Description: Small individuals 3-5 mm in length, 0.5-1 mm in width. Prostomium entire, caruncle to posterior margin of setiger 3, occipital tentacle short. Palps to setiger 13-18, extending approximately quarter of length of body. Branchiae from setiger 7 extending to setiger 20-22. Notosetae absent on setiger 1. Setiger 5 barely modified, with simple falcate spines (Fig. 7b) and curved pennoned spines, arranged in U-shaped line (Fig. 7c). Hooded neuropodial hooks from setiger 8, bidentate, completely replacing neuropodial capillaries. Pygidium a small flaring cup.

Comments: The South Australian material differs from the description of Blake & Kudenov in the number of branchiferous segments and relative lengths of the palps. Examination of this material, much of which is in poor condition indicates that the gills extend only to setiger 21-23, and not to setiger 35 as quoted by Blake & Kudenov, and this even for gravid females (NMV G3183).

Blake & Kudenov's material exhibits far greater variation in the shape of modified setae on setiger 5 (Fig. 7c-e) than exhibited by the South Australian material (Fig. 7a-b).

The type of *Pseudopolydora paucibranchiata* was destroyed during the Second World War. However material from the type locality should be examined to check the apparent wide distribution throughout the Pacific.

Australian distribution: S.A. (Porter Bay*, Torrens Island*) Vic. (Port Phillip Bay, Westernport Bay) N.S.W. (Jervis Bay, Botany Bay).

Habitat: Mudflats and seagrass beds.

Pseudopolydora sp. 1

FIG. 8a-c.

Material examined: S.A., 12A, 2 (W.19397). 12B, many (W.19398). 12C, 2 (W.19399). All posteriorly incomplete specimens.

Description: Colourless. Prostomium deeply incised, lobes widely flaring; small caruncle extends to posterior margin of setiger 3-4. Two pairs of eyes. Occipital tentacle absent. Setiger 1 without notosetae. Setiger 5 moderately modified, modified setae arranged in tight U, of 2 types, simple falcate spines (Fig. 8a) about 6, and pennoned spines (8), with 2 longitudinal ridges about concavity, dorsally finely hirsute (Fig. 8b-c). Hooded bidentate neurosetal hooks from setiger 8, in groups of about 13. Branchiae from setiger 7 to about setiger 25.

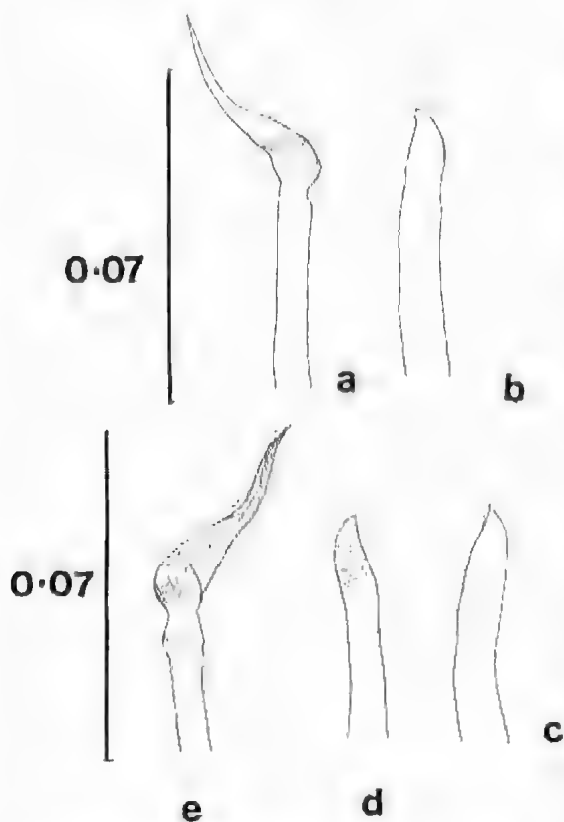


Fig. 7. *Pseudopolydora paucibranchiata* a-b. modified setae of setiger 5 (W.1727), S. Australian material. c-e, modified setae of setiger 5 (NMV G3183, NMV G3180) Victorian material. Scales in mm.

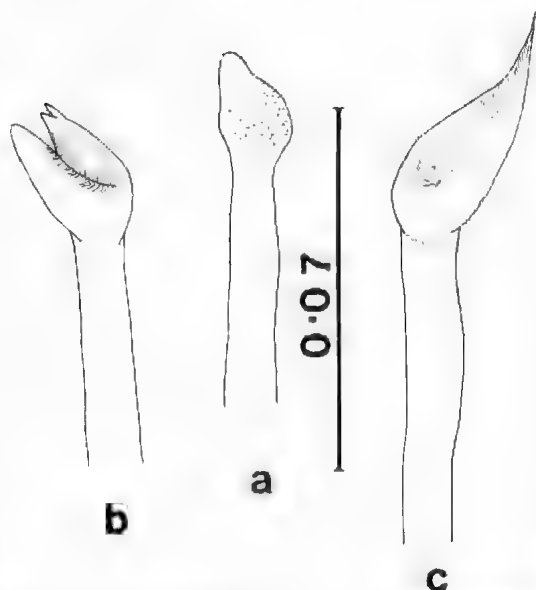


Fig. 8. *Pseudopolydora* sp. 1 a-c modified setae of setiger 5 (W.19398). Scales in mm.

Comments: This species differs from both *Pseudopolydora antennata* and *P. paucibranchiata* which occur in South Australia, and also differs from other described species from SE Australia. *Pseudopolydora* sp. 1 differs from these other described from SE Australia, *P. kempi* (Southern, 1921), *P. glandulosa* Blake & Kudenov, 1978, *P. stolonifera* Blake & Kudenov, 1978 and *P. prolifera* (Augener, 1914) in the type and ornamentation of the modified setae on setiger 5. It probably represents an undescribed species, but we have only incomplete specimens and as the genus we believe is in need of a re-evaluation we have decided not to describe another new species.

Habitat: This species occurs around Torrens Island Power Station, both in the thermally polluted areas where temperatures may exceed 40°C and in the non thermally polluted areas.

***Pseudopolydora* sp. 2**

FIG. 9a-b.

Material examined: S.A., 12C, 1 (W.194034).

Descriptions Colourless. Entire specimen, 57 setigers. Prostomium entire, rounded. Eye spots present, caruncle and occipital tentacle present but damaged; setiger 1 small, lacking notosetae. Setiger 5 barely modified not enlarged, modified setae arranged in small U shaped group, consisting of numerous fine pennoned (Fig. 9b) and falcate spines (Fig. 9a). Hooded multidentate neurosetal hooks

from setiger 7 and unidentate notosetal hooks from setiger 14, immediately completely replacing capillaries. Multidentate hooks with a group of small denticles closely above main fang, numbers of teeth cannot be determined. Branchiae from setigers 7-24. Pygidium, an anal collar, notched dorsally.

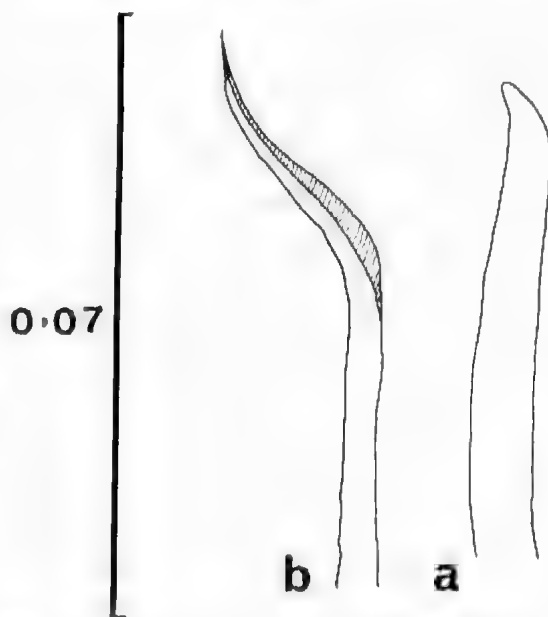


Fig. 9. *Pseudopolydora* sp. 2 a-b modified setae of setiger 5. Scales in mm.

Comments: This species clearly differs from *P. antennata* or *P. pseudopolydora* as identified by us. As there appears to be some confusion within this genus and we have only a single specimen, we have decided to just refer it to genus, although it clearly differs from all species of this genus currently described from Australia. We are also reluctant to describe a new species on a poorly preserved single specimen.

Habitat: Mud flats.

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SPECIES OF CERATOBAEUS ASHMEAD (HYMENOPTERA: SCELIONIDAE) FROM SOUTH-EASTERN AUSTRALIA

BY A. D. AUSTIN

Summary

Five species of *Ceratobaeus* Ashmead that were previously ill-defined are redescribed to facilitate their accurate identification. Types are designated for *Ceratobaeus clubionus* Austin, *C. cuspicornutus* Austin and *C. masneri* Austin. *Ceratobaeus intrudae* sp. nov., *C. platycornutus* sp. nov. and *C. rieki* sp. nov. are described and the male of *C. setosus* Dodd is recorded for the first time. Notes on the diagnosis, biology and distribution of the above species, and some general comments on the genus in Australia, are also provided.

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Summary

AUSTIN, A. D. (1984) Species of *Ceratobaeus* Ashmead (Hymenoptera: Scelionidae) from South Eastern Australia. *Trans. R. Soc. S. Aust.* **108**(1), 21-34, 12 June, 1984.

Five species of *Ceratobaeus* Ashmead that were previously ill-defined are redescribed to facilitate their accurate identification. Types are designated for *Ceratobaeus clubionus* Austin, *C. cuspidatus* Austin and *C. masneri* Austin. *Ceratobaeus invidiosus* sp.nov., *C. platycornutus* sp.nov. and *C. ricki* sp.nov. are described and the male of *C. setosus* Dodd is recorded for the first time. Notes on the diagnosis, biology and distribution of the above species, and some general comments on the genus in Australia, are also provided.

KEY WORDS: *Ceratobaeus*, Scelionidae, Araneae, ovipositor, host specificity.

Introduction

Ceratobaeus Ashmead is a large genus containing at least 40 described species. They occur worldwide, but are most diverse in the tropics and subtropics. Available host records¹ suggest that members of *Ceratobaeus* are exclusively parasites of spider eggs. They display a high degree of host specificity and cause significant levels of mortality for some spiders (Austin, in press).

The majority of Australian *Ceratobaeus* were described in the early part of this century by A. P. Dodd (1913, 1914a, 1914b, 1915, 1919), mostly from material collected by himself and A. A. Girault along the Queensland coast. Subsequently, Girault (1926) described a further species from Queensland, and V. V. Hickman (1967) described three species from Tasmania, which he reared from known spider hosts. Since then Austin (1981) has listed and placed the types of Australian species according to modern concepts, and Galloway & Austin (in press) have provided a diagnosis of the genus, along with a discussion of its biology, distribution and relationships with other genera.

The aim of the present paper is to describe three new species from south-eastern Australia, and to redefine a further five species whose descriptions are presently inadequate. Three

of the latter species (*C. clubionus*, *C. cuspidatus* and *C. masneri*) were referred to by Austin (1983) in a study of ovipositor mechanics of *Ceratobaeus* and related genera. Although he states that the names adopted are manuscript names only, the information presented in that paper constitutes their valid description under the International Code for Zoological Nomenclature (ICZN Articles 11, 13). However, the description of these species, along with those of *C. lamponae* (Hickman) and *C. setosus* Dodd, are inadequate in that they do not separate the species concerned from other species of *Ceratobaeus*. The status of these eight species is clarified here so that information from concurrent studies on their ecology (Austin in press; in prep.) can be published free of any taxonomic problems. Notes are provided on their distribution, hosts and relationships with other species. Additional diagnostic characters and general comments for the genus are also provided, which supplement those in Galloway & Austin (in press).

Methods

Specimen collection and preparation: Live wasps were obtained by rearing them from eggs of host spiders collected from the field. This provided valuable supportive information on host relationships and general biology. Other material was collected using yellow pan-traps and sweep-netting.

Specimens examined under SEM were prepared as follows: fresh material was killed, washed in 70% ethanol (5 min.), transferred to 100% ethanol (2 min.), and placed on a glass slide in a desiccator to dry (24 hr). Dry material (museum specimens) was softened in

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¹ Austin, A. D. (1982). The biology and ecology of *Clubiona* species (Araneae: Clubionidae) and their scelionid parasitoids (Hymenoptera). Ph.D. thesis, University of Adelaide. Unpubl.

10% ethanol (30 min.) and treated as above. Specimens were then mounted on holders with electroconductive glue (DAG 915 silver paint) or double-sided adhesive tape, coated with 10 nm carbon and 30 nm gold-palladium, and viewed under an ETEC Autoscan SEM operated at 5–20 keV. Some specimens were examined uncoated using the SEM in the Environmental Chamber Mode (Robinson 1980).

Material examined: The types of species described here, with the exception of *C. ricki*, were reared from a single host egg sac to ensure that the sexes of each species could be associated accurately (they are likely to be the offspring of one female). Males of some *Ceratobaeus* species are morphologically very similar and are difficult to separate. Therefore, the material listed in "Non-type specimens examined" has not been included in the type series in case males of other species have been wrongly associated. However, the chances of this having happened are slight, as there appears to be only a few species that attack hosts inhabiting the bark of eucalypt trees, the habitat from where most of the present species were collected. In most cases only one paratype female and male were coated for SEM: holotypes and allotypes were mounted on card-points so as to retain their colour.

Terminology: Morphological terms used throughout this paper are defined in Masner (1980) and Galloway & Austin (in press).

Abbreviations: ANIC = Australian National Insect Collection, CSIRO, Canberra; BMNH = British Museum (Natural History), London; CNC = Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa; QDPI = Queensland Department of Primary Industries, Brisbane; SAM = South Australian Museum, Adelaide; WAITE = Waite Agricultural Research Institute, Adelaide; A.D.A. = specimens collected by A. D. Austin; Caringbah = a suburb of Sydney; Mylor = study site, 5 km south of Mylor, South Australia; H = height; L = length; W = width; S = metasomal sternite; T = metasomal tergite.

Genus CERATOBAEUS Ashmead

Ceratobaeus Ashmead 1893, pp. 167, 175; Kieffer 1926, p. 139; Masner 1976, p. 65; Huggert 1979, p. 7; Austin 1981, p. 83; Galloway & Austin (in press).

Type-species, *Ceratobaeus cornutus* Ashmead

Diagnosis: The genus has been adequately diagnosed in Masner (1976) and Galloway & Austin (in press); however, some additional useful characters are given below.

Head viewed anteriorly usually triangular or subtriangular in shape, sometimes with genae prolonged so as to be conical in shape towards the mandibles (similar to the condition in *Odontacolus* Kieffer).

Forewings. Venation clearly delineated though sometimes only lightly coloured, with at least submarginal, marginal and stigmal veins present.

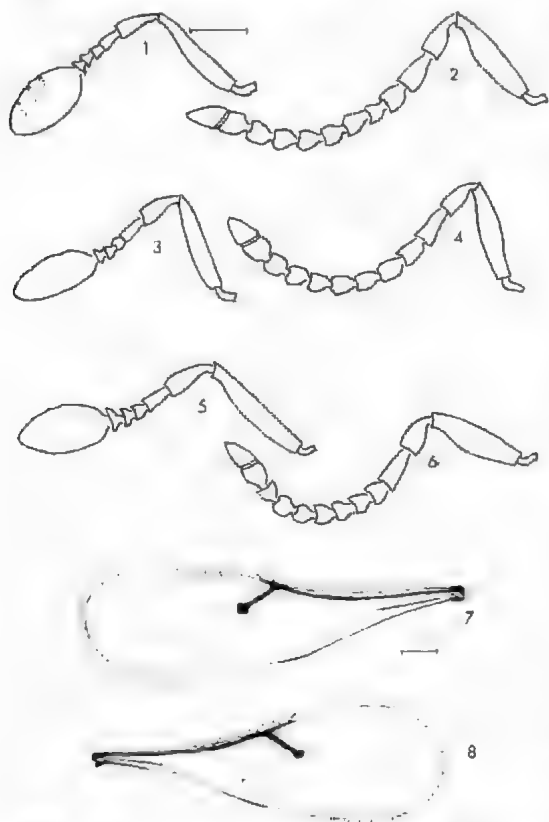
Metasoma. T7 external in female, usually triangular in shape, always visible when viewed from above; ovipositor held internally, extending to the apical end of horn on T1 (therefore as long as metasoma).

Comments: Of the genera comprising the tribe Idrini (see Austin 1981), *Ceratobaeus* is most closely related to *Idris*. Huggert (1979) has proposed that *Ceratobaeus* should be included under *Idris* as a subgenus, due to the apparent existence of intermediate forms. However, Austin (1981) maintains that they should be kept separate due to differences in the morphology of the metasoma and posterior mesosoma. *Idris* differs from *Ceratobaeus* in that T1 is always flat, the metasoma is never elongated, the propodeum is not excavated, and the propodeal disc is not divided into laminae. Also the length of the ovipositor differs between these two genera. *Ceratobaeus* species have very long ovipositors that are held internally within the metasoma and extend into the anteriorly projecting horn of T1. *Idris* species, however, have relatively short internal ovipositors that do not reach past the posterior margin of T2 (Austin 1983).

The length of the metasoma and horn vary substantially between species of *Ceratobaeus*, but remain constant within a species. In some species the horn is represented by a small hump, while in others it reaches dorsally above the mesosoma. The various stages in horn and metasomal length between these two extremes results in there being a corresponding series in the length of the ovipositor. Presumably such differences have evolved in response to varying accessibility of host eggs. Ovipositor length is well recognised as a factor involved in determining host specificity and subsequent speciation within the parasitic Hymenoptera (e.g. Askew 1971; Gibbons 1979; Heathcote &

Davis 1976; Price 1972), and undoubtedly a similar mechanism has operated in *Ceratobaeus*.

The morphology of the posterior mesosoma is closely tied to the size of the horn: species with large horns have the propodeum and scutellum more excavated than in species with short horns. Although males of *Ceratobaeus* have at most only a slight dorsal expansion on T1, many species still display some excavation of the posterior mesosoma. This excavation is always more pronounced in males of species where the female has a long horn (e.g. *C. cuspicornutus*, fig. 12).



Figs 1-6. Antennae. 1. *Ceratobaeus cuspicornutus*, ♀, 2. *C. cuspicornutus*, ♂, 3. *C. masneri*, ♀, 4. *C. masneri*, ♂, 5. *C. platycornutus*, ♀, 6. *C. platycornutus*, ♂. Figs 7, 8. Forewings. 7. *C. cuspicornutus*, ♀, 8. *C. masneri*, ♀. Scale lines = 100 μ m. N.B. hairs and cilia not drawn on antennae and wings.

Ceratobaeus clubionus Austin
FIGS 9-11, 15, 17, 18

Ceratobaeus clubionus Austin 1983, p. 151 (no types designated).

Types (by present designation): holotype ♀, ANIC, South Australia; Mylor, 29.iii.1979, A.D.A., ex egg *Clubion* sp. (Araneae). Paratypes reared from same egg sac as holotype—Allotype ♂, ANIC; Paratypes 2♂, 2♀, gold coated on SEM holders, antennae and wings of 1♂, 1♀ on slides, 1♂, 4♀, ANIC; 1♂, 4♀, CNC; 1♂, 4♀, QDPI; 1♂, 4♀, SAM; 1♂, 4♀, WAITE.

Female

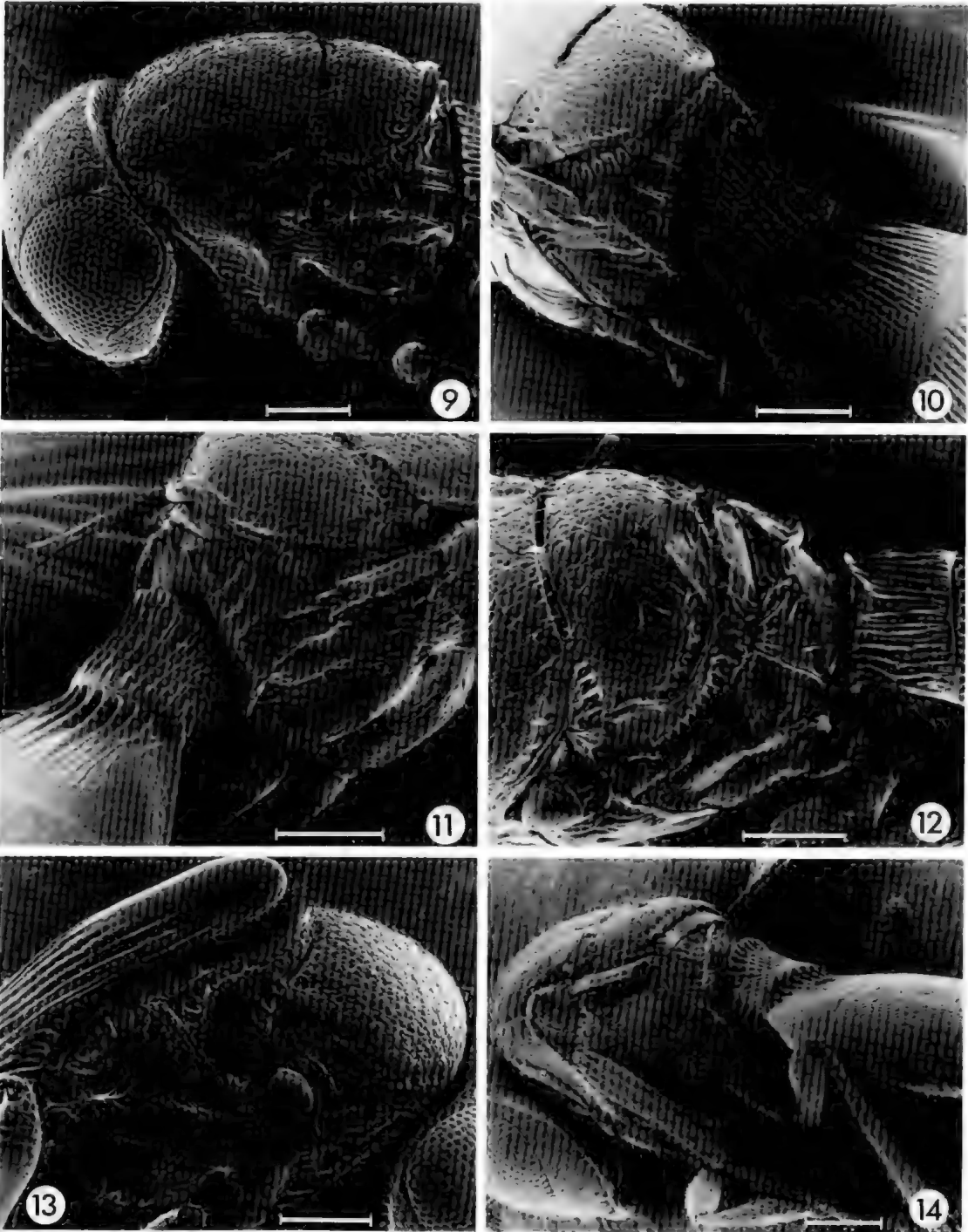
Length 1.3-1.4 mm. Colour, Head and mesosoma shiny black; antennae and legs light brown, almost yellow; antennal clubs and femora slightly darker; metasoma dark brown with lighter margin; posterior T1 and anterior T2 light brown.

Head, L:W:H (6.5:19:14), with granulate sculpturing and fine scattered hairs; dorsally, wider than mesosoma and arched around pronotum; occipital carina sharp; eyes large and hairy; lateral ocelli touching inner margins of eyes; frons slightly curved; anteriorly, head ovoid; occiput arched; eyes separated by 0.5 \times width of head; frons smooth; frontal carina weakly developed; laterally, gena with sides not quite parallel; antenna (fig. 17), club with 3 faint incomplete sutures.

Mesosoma. Dorsally, with coriaceous sculpturing and sparse short hairs (fig. 9); pronotum not visible; scutum wider than long, L:W (11:14); notauli absent; scutellum almost semi-circular, L:W (5.5:11), posterior margin with wide flange extending over metanotum, slightly inflexed medially; metanotum narrow and crenulated; propodeum vertical and smooth, laminae diverging ventrally, extended into 2 small teeth dorsally (fig. 10).

Forewings not quite reaching to posterior margin of metasoma, not particularly broad. L:W (36:13); venation distinct, marginal and postmarginal veins short; stigmal vein long, basal vein present but lighter than other veins; lightly infuscated around apex of stigmal vein; marginal fringe of hairs moderately long (fig. 15).

Metasoma wider than mesosoma, L:W (30:17), sparsely covered with hairs, pointed posteriorly; anterior T1 expanded into large hump, not reaching above propodeum (fig. 10); T1 and T2 with coarse longitudinal striations, T3 with lighter striations; lateral margins of T2-T3 and all T4-T6 with granulate sculpturing.



Figs 9-11. *Ceratobaeus clubionus*. 9. ♀, lateral view of mesosoma and T1. 10. ♀, dorsolateral view of mesosoma and T1. 11. ♂, dorsoposterior view of mesosoma and T1. Figs 12, 13. *C. cuspicornutus*. 12. ♂, dorsal view of mesosoma and T1. 13. ♀, lateral view of mesosoma and T1. Fig. 14. *C. intrudae*, ♂, lateral view of whole body. Wings removed on all specimens. Scale lines 100 μ m.

Male

Differing from female in the following: length 1.2–1.3 mm; antenna (fig. 18); propodeal laminae diverging slightly more than in female; wings reaching well past posterior margin of metasoma; forewing L:W (46:19), marginal fringe of hairs long, venation dark, basal vein darker than in female; metasoma rounded posteriorly, wider than mesosoma, L:W (26:18); anterior T1 inflected dorsally into hump, but not as pronounced as in female (fig. 11).

Comments

C. clubionus parasitises the eggs of *Clubiona cycladota* Simon and an undescribed species of *Clubiona* (Clubionidae). These spiders inhabit the bark of eucalypt trees in the Mount Lofty Ranges, South Australia. This species can be distinguished from all other *Ceratobaeus* by its colour, the presence of a postmarginal vein, and the horn on T1 represented by only an anterior dorsal inflection of that tergite, i.e. not rounded dorsally.

Non-type specimens examined: SOUTH AUSTRALIA: 2♂, 6♀, 15.iii.1979, 2♂, 13♀, 18.xi.1979, Mylor, A.D.A., 1♂, 7♀, Myponga, 4.ii.1979, A.D.A., ♂, 10♀, 3.ii.1979, 1♂, 5♀, 4.ii.1979, Strathalbyn, A.D.A. ANIC; 4♂, 27♀, Mylor, 1979, A.D.A.; 1♂, 1♀, Myponga, 4.ii.1979, A.D.A. BMNH; 8♀, 15.iii.1979, 1♂, 14♀, 13.iv.1979, Mylor, A.D.A. CNC; 1♂, 4♀, 13.ii.1979, 5♀, 9.iii.1979, 1♂, 5♀, 25.xi.1979, 1♂, 5♀, 7.xii.1979, Mylor, A.D.A. QDPI; 1♂, 5♀, 13.iv.1979, 2♂, 12♀, 20.i.1980, Mylor, A.D.A. SAM; 11♀, 23.i.1979, 2♂, 8♀, 13.ii.1979, Mylor, A.D.A. WAITE.

Ceratobaeus cuspidicornutus Austin

FIGS 1, 2, 7, 12, 13

Ceratobaeus cuspidicornutus Austin 1983, p. 151 (not types designated).

Types (by present designation): holotype ♀, ANIC, South Australia: Mylor, 18.ii.1979, A.D.A., ex egg *Clubiona* sp. (Araneae). Paratypes reared from same egg sac as holotype—Allotype ♂, ANIC; Paratypes 1♂, 2♀, gold coated on SEM holders, antennae and wings of ♂ and 1♀ on slides, 2♀ dissected on slides, 2♂, 2♀, ANIC; 1♂, 2♀, CNC; 1♂, 2♀, QDPI; 1♂, 2♀, SAM; 1♂, 2♀, WAITE.

Female

Length 1.50–1.75 mm. Colour. Head and mesosoma black; legs and antennae brown to dark brown; metasomal horn black and shiny; posterior T1 light brown; T2–T7 brown. Head wider than mesosoma, L:W:H (6:19:

15), with granulate sculpturing and short scattered hairs; dorsally, occipital carina sharp; eyes large, with very short hairs; lateral ocelli touching inner margins of eyes; frons slightly curved; anteriorly, head subtriangular in shape; occiput slightly depressed medially; eyes separated by slightly more than $0.5 \times$ width of head; lower frons smooth and shiny; frontal carina weakly developed; laterally, gena large, margins parallel; antenna (fig. 1), club with 3 faint incomplete sutures.

Mesosoma strongly compressed anteroposteriorly; dorsally, with granulate sculpturing and scattered hairs; pronotum not visible; scutum much wider than long, L:W (9:14); notauli absent; scutellum transverse, L:W (1:10), with posterior fringe of long hairs; scutellum, metanotum and propodeum strongly excavated to receive horn, sloping away posteriorly towards metasoma; propodeal laminae parallel, not extended dorsally into small teeth (fig. 13); laterally mesosoma smooth and shiny.

Forewings not reaching past posterior margin of T4, fairly narrow, L:W (44:13); marginal vein short, stigmal vein long, postmarginal vein less than $0.5 \times$ length of stigmal vein; marginal fringe of hairs moderately long (fig. 7).

Metasoma elongated, L:W including horn (55:17), slightly wider than mesosoma, with scattered hairs; horn long, angled forward into mesosomal cavity, reaching above level of scutellum; apical horn moderately pointed and smooth, striate laterally and basally (fig. 13) base of T1–T4 with longitudinal striations; lateral margins of T2–T3 and all T4–T7 with granulate sculpturing; T7 slightly elongated.

Male

Differing from female in the following: length 1.35–1.50 mm; antenna (fig. 2); dorsal mesosoma arched more than in female; scutellum more than $2 \times$ wider than long, L:W (5:12), posterior margin rounded, inflected medially into small smooth triangular patch; posterior mesosoma not excavated but flat, sloping posteriorly towards metasoma; metanotum narrow and crenulated, visible from above; propodeum smooth; propodeal laminae diverging ventrally (fig. 12); wings reaching well past posterior metasoma; forewings moderately broad, L:W (55:20), basal vein darker than in female, but still faint compared to submarginal vein, marginal fringe of

hairs long; metasoma moderately elongated, rounded posteriorly, L:W (29:16); anterior T1 inflected dorsally, striations reaching to anterior margin of T1.

Comments

This species parasitises the eggs of *Clubiona cycladata* and an undescribed species of *Clubiona* (Clubionidae). These spiders inhabit the bark of eucalypt trees in the Mount Lofty Ranges, South Australia. *C. caespicornutus* is related to a group of species that all have a long slightly curved horn and an elongate metasoma. It comes closest to *C. longicornutus* Dodd, but differs in having a darkly pigmented basal vein, a brown metasoma (not yellow) and a more elongate antennal pedicel.

Non-type specimens examined: SOUTH AUSTRALIA: 3♂, 9♀, 9.iii.1979, 10♀, 13.xi.1979, Mylor, A.D.A., ANIC; 2♂, 6♀, Mylor, 27.xii.1980, A.D.A., BMNH; 2♂, 4♀, Mylor, 15.iii.1979, A.D.A., CNC; 1♂, 6♀, Mylor, 13.xi.1979, A.D.A., QDPI; 2♂, 5♀, Mylor, 9.ix.1979, A.D.A., SAM; 2♀, 29.iii.1979, 3♀, 26.iii.1978, Mylor, A.D.A., WAITE.

Ceratobaeus intrudae sp. nov.

FIGS 14, 16, 19–22

Types: holotype ♀, ANIC, South Australia: Mt Compass, 4.ii.1979, A.D.A., ex egg *Intruda* sp. (Araneae). Paratypes reared from same egg sac as holotype—Allotype ♂, ANIC; Paratypes 1♂, 1♀, gold coated on SEM holders, antennae and wings on slides, 2♂, 2♀, dissected on slides, ANIC; 1♂, 1♀, CNC.

Female

Length 1.30–1.45 mm. Colour. Head and dorsal mesosoma very dark brown to black; legs, antennae and lateral mesosoma dark brown; metasoma with a light brown band behind horn and a medial brown patch occupying approximately two-thirds of T3, rest of metasoma dark brown to black.

Head wider than mesosoma, not strongly curved around pronotum, with granulate sculpturing and sparse short hairs, L:W:H (7.5:18:13); dorsally, occipital carina sharp; eyes large, covered with short hairs; lateral ocelli touching inner margins of eyes; frons slightly curved; anteriorly, head subtriangular in shape; occiput flat; eyes separated by more than 0.5 × width of head; frons lightly sculptured; frontal carina well developed, reaching half way to median ocellus; laterally, gena large, margins almost parallel; antenna (fig. 19), club with 3 faint incomplete sutures.

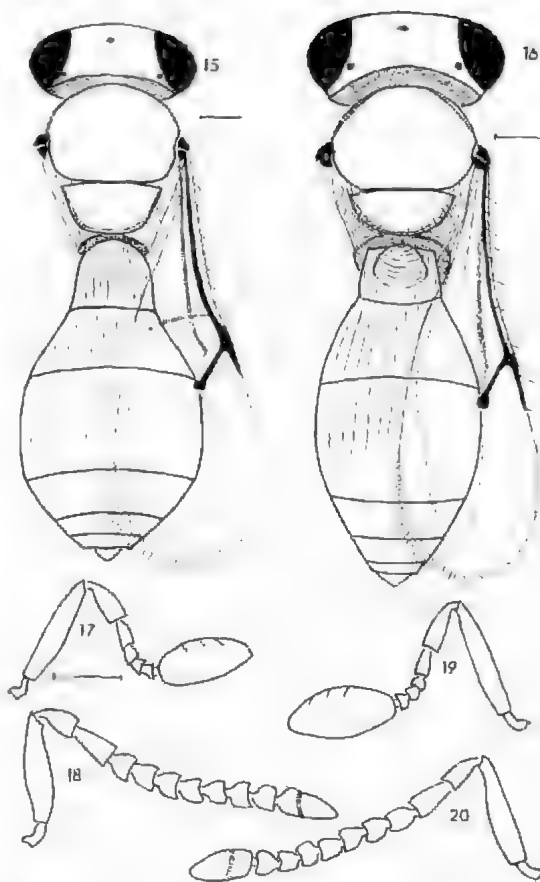


Fig. 15. *Ceratobaeus clubionus*, ♀, dorsal surface of whole body. Fig. 16. *C. intrudae*, ♀, dorsal surface of whole body. Figs 17–20. Antennae. 17. *C. clubionus*, ♀, 18. *C. clubionus*, ♂, 19. *C. intrudae*, ♀, 20. *C. intrudae*, ♂. Scale lines = 100 µm. N.B. hairs and cilia not drawn on antennae and wings.

Mesosoma. Dorsally, fairly flat, with granulate sculpturing and scattered hairs; pronotum visible at anterior corners; scutum wider than long, L:W (10:14.5); notauli absent; scutellum almost semi-circular, L:W (4:11), posterior border crenulated, with a narrow flange (fig. 22); metanotum narrow and crenulated; propodeum vertical and smooth; laminae curving dorsally, extended into 2 small teeth (fig. 21); laterally, mesosoma smooth and shiny.

Forewings narrow, not quite reaching to posterior margin of metasoma, L:W (38:12.5); marginal vein short, stigmal vein long, postmarginal vein as long as stigmal vein, basal vein present but very faint; infuscated around

apex of stigmal vein; marginal fringe of hairs short (fig. 16).

Metasoma slightly wider than mesosoma and $2 \times$ longer than wide, L:W (32:16), with scattered hairs, pointed posteriorly; horn almost vertical, just reaching above level of posterior scutellum, with circular striated sculpturing apically (figs. 21 and 22); T1 behind horn and T2-T3 with longitudinal striations; lateral T2-T3 and all T4-T6 with granulate sculpturing.

Male

Differing from the female in the following: dorsally, head slightly more curved around pronotum, only slightly wider than mesosoma, L:W:H (7.5:17:13); antenna (fig. 20); propodeum not quite vertical, sloping away slightly towards metasoma; propodeal laminae slightly wider than in female; wings reaching well past posterior metasoma; forewing L:W (42:16), marginal fringe of hairs long; metasoma rounded posteriorly, L:W (25:16); anterior T1 strongly inflected dorsally, not reaching above propodeal laminae; without striae or punctate sculpturing, but with longitudinal striations extending to anterior margin (fig. 14).

Comments

C. intrudae parasitises the eggs of an unknown species of *Intruda* (Gnaphosidae), the latter being found under the bark of eucalypt trees in the Mount Lofty Ranges, South Australia. This species is related to a large group, all with moderately short horns. However, *C. intrudae* can be distinguished from all other species by the following combination of characters: apical horn with circular striae, metasoma twice as long as wide, colour as in description.

Non-type specimens examined: SOUTH AUSTRALIA: 1♂, 3♀, Bridgewater, 26.iii.1979, A.D.A., ANIC; 1♂, 4♀, Bridgewater, 26.iii.1978, A.D.A., SAM.

Ceratobaeus lamponae (Hickman)

FIGS 23-25

Odontacolus lamponae Hickman 1967, p. 18.

Ceratobaeus lamponae (Hickman); Masner 1976, p. 66; Austin 1981, p. 84.

Types: holotype ♀ on slide, ANIC: Tasmania, Domain, Hobart, 29.xii.1966, V. V. Hickman, ex egg *lampona cylindrata* (L. Koch) (Araneae); Paratypes 2♂, 1♀, on same slide as holotype

Female

Length 1.60-1.85. Colour, Head, mesosoma and horn shiny black; antennae and metasoma dark brown to black; legs brown.

Head, L:W:H (9:22.5:16), with moderately coarse punctate-reticulate sculpturing, covered with long hairs; dorsally, wider than mesosoma, arched around pronotum; occiput well exposed; occipital carina sharp, moderately angled at corners; eyes large, with long hairs; lateral ocelli touching inner margins of eyes; frons straight; anteriorly, head subtriangular in shape; occiput straight; eyes separated by slightly less than $0.5 \times$ width of head; frons flat, with horizontal striae; frontal carina very small; laterally, gena with margins parallel, rounded ventrally; antennal scape L:W (31:6), pedicel (13:5.5), club (27:12) with 3 faint incomplete sutures.

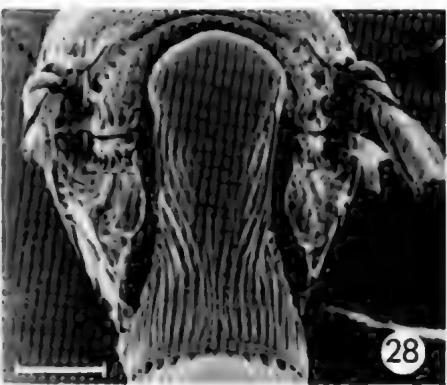
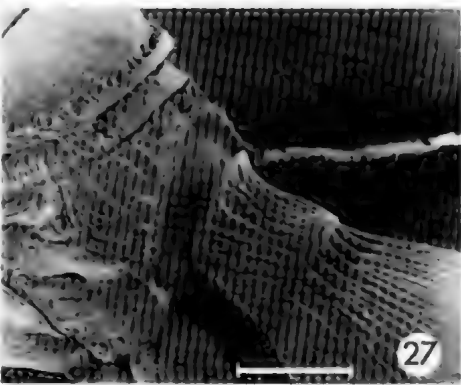
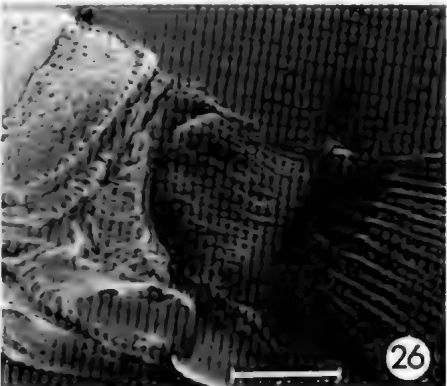
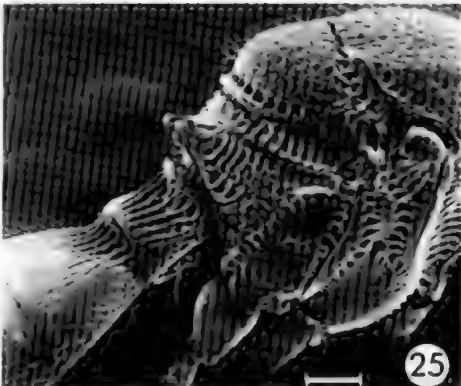
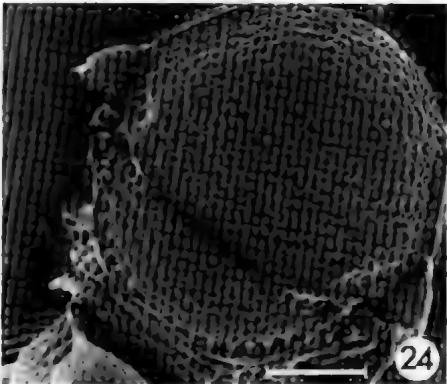
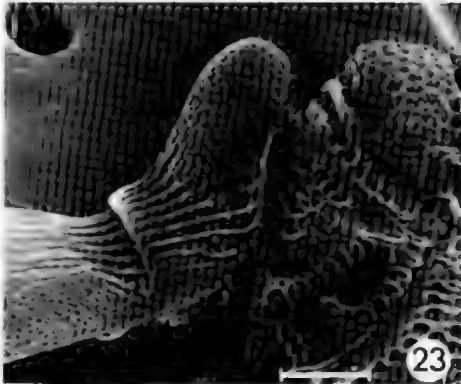
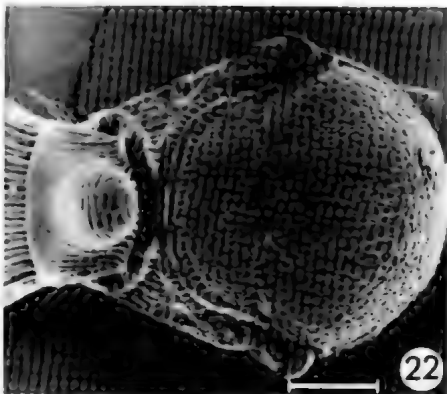
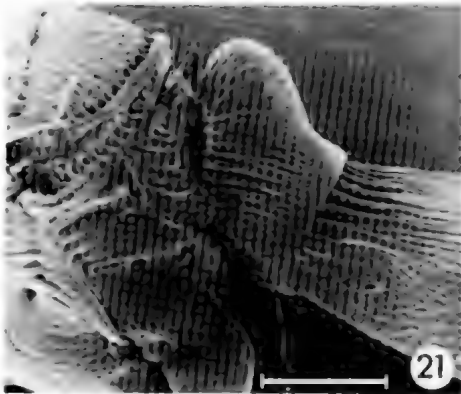
Mesosoma dorsally, with moderately coarse punctate-reticulate sculpturing, sparsely covered with long hairs (fig. 24); pronotum visible at anterior lateral corners; scutum wider than long; L:W (13.5:17.5); notauli absent; scutellum almost $3 \times$ wider than long, L:W (4:12), posterior margin straight, fringe of long hairs projecting over horn often present; metanotum and propodeum flat; metanotum narrow and crenulated; propodeal laminae diverging ventrally, extended dorsally into blunt teeth; lateral propodeum and mesopleura margined by single rows of deep pits (fig. 23).

Forewings not quite reaching to posterior margin of metasoma, moderately broad, L:W (73:27), infuscated medially; venation clear and dark; marginal vein short, postmarginal vein as long as stigmal vein, basal vein light; marginal fringe of hairs moderately long.

Metasoma wider than mesosoma, L:W including horn (42:22), covered with long hairs; horn just reaching to level of dorsal scutellum, apical two-thirds with coriaceous sculpturing almost scaly in appearance (fig. 23); T1 including basal one-third of horn and T2 with longitudinal striations, T3 strigose with background granulate sculpturing, T4-T6 with granulate sculpturing.

Male

Differing from female in the following: length 1.55-1.70 mm; dorsally, scutellum more rounded, though slightly flattened posteriorly, $2 \times$ wider than long, L:W (6.5:



12.5); propodeum flat, almost vertical; propodeal laminae wide, with coarse striate sculpturing, strongly diverging ventrally, extended into 2 blunt teeth dorsally which almost touch medially (fig. 25); wings reaching well past posterior metasoma; forewing L:W (83:32), well infuscated, marginal fringe of hairs long; metasoma subpedunculate, wider than mesosoma, with scattered long hairs, L:W (35:25), anterior T1 inflected dorsally; T1-T2 and anterior T3 with longitudinal striations, lateral T2 and rest of metasoma with granulate sculpturing.

Comments

C. lamponae (Hickman) parasitises the eggs of *Lampona cylindrata* (L. Koch) (Gnaphosidae); the latter being widespread throughout Australia. *C. lamponae*, previously only known from Tasmania, is recorded from mainland Australia (Mount Lofty Ranges, South Australia) for the first time. There appears to be some minor geographic variation in this species. Some specimens from Tasmania have the posterior fringe of hairs on the scutellum very short or absent, while mainland specimens have a very long fringe. *C. lamponae* can be distinguished from other species by its colour, presence of a postmarginal vein and characteristic sculpturing on the horn and dorsal mesosoma.

Non-type specimens examined: SOUTH AUSTRALIA: 1♂, 1♀, gold coated on SEM holders, antennae and wings on slides, 2♂, 11♀, Mylor, 29.iii.1979, A.D.A., ANIC; 6♂, 10♀, Mylor, 20.i.80, Mylor, A.D.A., BMNH; 4♂, 8♀, Mylor, 20.i.1980, A.D.A., CNC; 1♂, 11♀, Mylor, 29.iii.1979, A.D.A., QDPI; 4♂, 6♀, Mylor, 20.i.1980, A.D.A., SAM; 1♂, 6♀, Mylor, 14.xii.1979, A.D.A., WAITE. TASMANIA: 1♂, 11♀, Domain, Hobart, 9.iii.1967, V. V. Hickman, ANIC; 3♂, 11♀, Domain, Hobart, 29.xii.1967, V. V. Hickman, CNC.

Ceratobaeus masneri Austin

FIGS 3, 4, 8, 26, 27

Ceratobaeus masneri Austin 1983, p. 143 (no types designated).

Types (by present designation): holotype ♀, ANIC, South Australia; Mylor, 18.ii.1979, A.D.A., ex egg *Clubiona* sp. (Araneae). Paratypes reared

from same egg sac as holotype—Allotype ♂, ANIC; Paratypes 2♂, 3♀, gold coated on SEM holders, antennae and wings of 1♂, 1♀ on slides, 4♂, 4♀, ANIC; 1♂, 4♀, CNC; 1♂, 4♀, QDPI; 1♂, 4♀, SAM; 1♂, 4♀, WAITE.

Female

Length 1.25–1.40 mm. Colour. Head and mesosoma black; antennae and legs brown; metasoma dark brown; T1 light brown, but with apex of horn brown to dark brown.

Head wider than mesosoma. L:W:H (7:18:13), arched around pronotum, with granulate sculpturing and scattered short hairs; dorsally, occipital carina sharp; eyes large and hairy; lateral ocelli touching inner margins of eyes; frons curved; anteriorly, head subtriangular in shape; occiput curved; eyes separated by slightly more than 0.5 × width of head; frons smooth; frontal carina weakly developed, reaching 0.5 × distance to median ocellus; laterally, gena wide, sides not parallel; antenna (fig. 3).

Mesosoma. Dorsally, with granulate sculpturing and scattered hairs; pronotum not visible; scutum wider than long, L:W (9:12); notauli absent; scutellum L:W (4.5:10), rounded posteriorly, with crenulated border, slightly inflected medially; metanotum narrow and crenulated; propodeum vertical and smooth; laminae diverging ventrally and curved dorsally into 2 small teeth, laterally with coarse striations. (fig. 26).

Forewings just reaching to posterior margin of metasoma, fairly narrow, L:W (40:13); marginal vein short, stigmal vein long, post-marginal vein approximately 0.75 × length of stigmal vein, basal vein present but faint; marginal fringe of hairs short (fig. 8).

Metasoma wider than mesosoma, nearly 2 × longer than wide, L:W (35:19), pointed posteriorly, sparsely covered with hairs; T1 expanded into a small dorsal horn, not reaching to level of scutellum (fig. 26); apex of horn with faint punctate sculpturing; most of horn, posterior T1 and T2-T3 with longitudinal striations; lateral margins of T2, background of T3 and all T4-T6 with granulate sculpturing.

Figs 21, 22. *Ceratobaeus intrudae*, ♀. 21. Lateral view of mesosoma and T1. 22. Dorsal view of mesosoma and T1. Figs 23–25. *C. lamponae*. 23. ♀, lateral view of mesosoma and T1. 24. ♀, dorsal view of mesosoma. 25. ♂, lateral view of mesosoma and T1. Figs 26, 27. *C. masneri*. 26. ♀, dorsolateral view of mesosoma and T1. 27. ♂, dorsolateral view of mesosoma and T1. Fig. 28. *C. platycornutus*, ♀, dorsoposterior view of mesosoma and T1. Wings removed on all specimens. Scale lines — 100 µm.

Male

Differing from female in the following: length 1.20–1.35 mm; antenna (fig. 4); hairs on dorsal surface of mesosoma slightly longer than in female; scutellum slightly arched dorsally; lateral propodeum with fine sparse striations; wings reaching well past posterior margin of metasoma; forewing L:W (49:18), venation same as female, but with basal vein more obvious, almost as dark as submarginal vein, marginal fringe of hairs long; metasoma rounded posteriorly, L:W (27:16.5); anterior T1 inflected dorsally, only reaching to 0.5 × height of propodeum, striations reaching to anterior margin of T1 (fig. 27).

Comments

C. masneri parasitises the eggs of *Clubiona robusta* L. Koch, *Cl. cycladata*, an undescribed species of *Clubiona* (Clubionidae) and *Hemiclea* sp. (Gnaphosidae): all inhabit the bark of eucalypt trees throughout south-eastern Australia. So far *C. masneri* has been collected from locations in South Australia, Victoria and the Australian Capital Territory. This species belongs to a large group that all have short horns. However, *C. masneri* can be recognised from all other species by the presence of a postmarginal vein, a darkly pigmented basal vein, and its colour (see description).

Non-type specimens examined: AUSTRALIAN CAPITAL TERRITORY: 6♂, Canberra, 14.i.1980, A.D.A., ANIC. SOUTH AUSTRALIA: 13♀, 20.i.1979, ex eggs *Clubiona* sp. (Araneae), 6♂, 14♀, 13.xi.1979, ex eggs *Hemiclea* sp. (Araneae), Mylor, A.D.A., ANIC; 10♂, 17♀, Mylor, 1978–80, A.D.A., 1♀, Myponga, 4.ii.1979, A.D.A.; 7♂, 33♀, Mylor, 10.iii.1980, A.D.A., ex eggs *Hemiclea* sp., CNC; 4♂, 6♀, 1.xii.1979, 2♂, 6♀, 20.i.1980, Mylor, A.D.A., QDPI; 5♂, 6♀, Mylor, 17.ii.1980, A.D.A., SAM; 7♀, 15.iv.1979, 11♀, 12.viii.1979, Mylor, A.D.A., WAITE. VICTORIA: 1♂, 9♀, Woorndoo, 26.ix.1979, A.D.A., SAM.

Ceratobaeus platycornutus sp. nov.

FIGS 5, 6, 28, 29

Types: holotype ♀, ANIC, Australian Capital Territory: University campus, Canberra, 14.i.1980, A.D.A., ex egg *Clubiona* sp. (Araneae). Paratypes

reared from same egg sac as holotype—Allotype ♂, ANIC; Paratypes 2♂, 2♀, gold coated on SEM holders, antennae and wings of 1♂, 1♀ on slides, 2♂, 7♀, ANIC; 1♂, 4♀, CNC; 1♂, 4♀, QDPI; 1♂, 4♀, WAITE.

Female

Length 1.75–1.85 mm. Colour. Head, mesosoma and apical horn black; antennae, legs and metasoma dark brown; anterior metasoma behind horn with a light brown band.

Head wider than mesosoma, L:W:H (7:20:15), arched around pronotum, with granulate sculpturing, sparsely covered with hairs; dorsally, occipital carina sharp; eyes large, with fine hairs; lateral ocelli touching inner margins of eyes; frons curved; anteriorly, head subtriangular in shape; occiput straight; eyes separated by 0.5 × width of head; frons lightly punctate; frontal carina very small; laterally, gena wide, sides almost parallel; antenna (fig. 5).

Mesosoma strongly compressed antero-posteriorly; dorsally, with granulate sculpturing and scattered hairs; pronotum not visible; scutum wider than long, L:W (10:15); notauli absent; scutellum transverse, L:W (1:10), scutellum, metanotum and propodeum all strongly indented posteriorly, sloping towards metasoma; propodeal laminae vertical, curved outwards ventrally, without dorsal teeth (fig. 28).

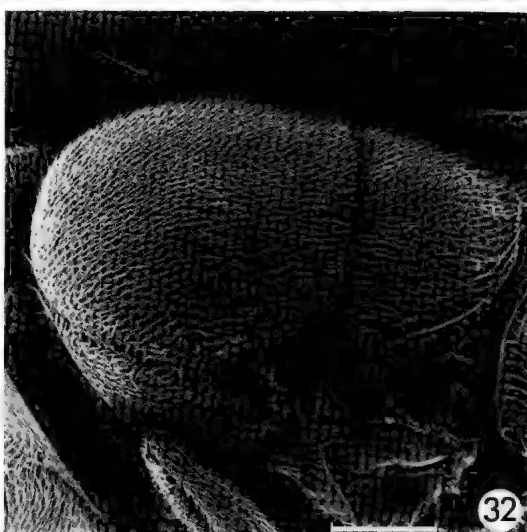
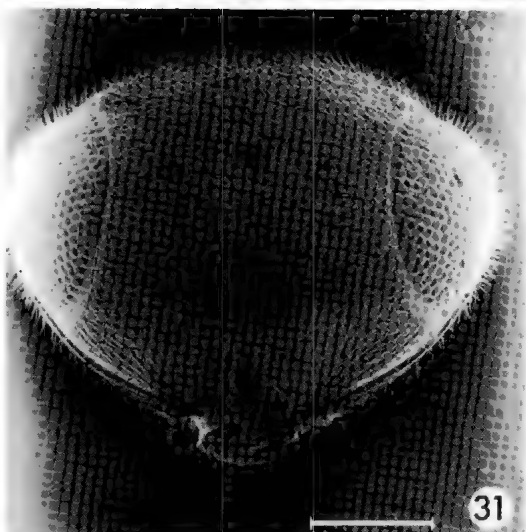
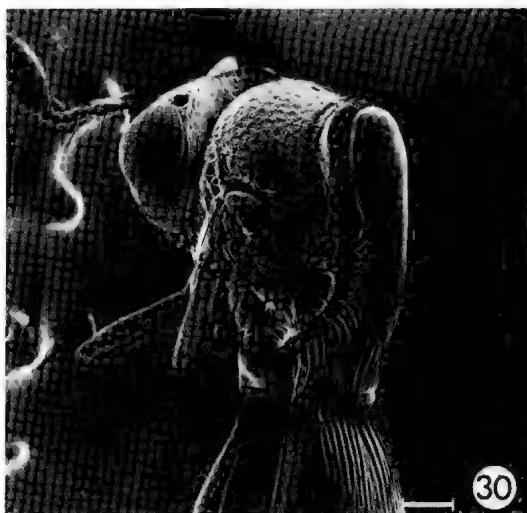
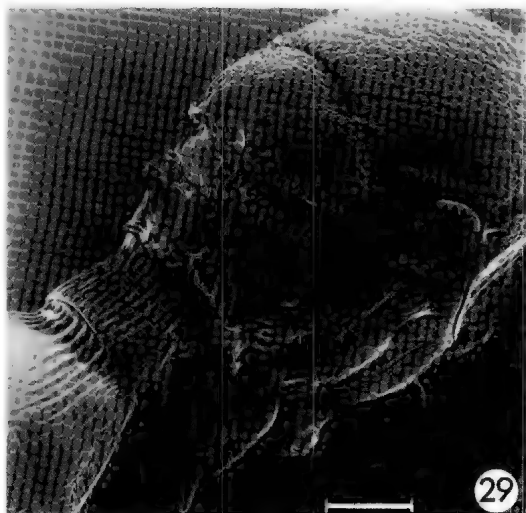
Forewings reaching to posterior margin of T4, fairly narrow, L:W (71:23); lightly infuscated medially; marginal vein short, stigmal vein long, postmarginal vein less than 0.5 × length of stigmal vein, basal vein light; marginal fringe of hairs moderately long.

Metasoma elongated, L:W including horn (56:18), wider than mesosoma; horn long, slightly arched, projecting anteriorly, closely fitting to mesosoma, reaching above level of scutellum, flattened and disc-shaped apically (fig. 28); T1 except for apical portion of horn and T2–T4 with longitudinal striations; lateral T2–T4 and all T5–T7 with light granulate sculpturing.

Male

Differing from female in the following: length 1.4–1.5 mm; antennae and legs yellow;

Fig. 29. *Ceratobaeus platycornutus*, ♂, dorsolateral view of mesosoma and T1. Fig. 30. *C. rleki*, ♀, dorsolateral view of head, mesosoma and T1. Figs 31–34. *Ceratobaeus setosus*, 31. ♀, anterior view of head, antennae missing. 32. ♀, dorsolateral view of mesosoma. 33. ♀, lateral view of mesosoma and T1. 34. ♂, lateral view of mesosoma and T1. Wings removed on all specimens except on one side of specimens in Figs. 32 and 33. Scale bars = 100 µm.



metasoma dark brown to black, with light brown band anteriorly; antenna (fig. 6); head not as high, L:W:H (7:20:13.5); scutellum almost semicircular, slightly indented posteriorly to form smooth triangular patch; metanotum and propodeum flattened and smooth; propodeal laminae diverging ventrally; wings reaching well past metasoma; forewings broad, L:W (80:31), postmarginal vein not as long as in female, basal vein slightly darker, marginal fringe of hairs long; metasoma not as elongated, L:W (30:20); anterior T1 inflected dorsally (fig. 29); T1–T3 with longitudinal striations; rest of metasoma with light punctate sculpturing.

Comments

The specific name *platycornutus* (*platys* in Latin, broad or flat; *cornutus*, horn) refers to the flattened, disc-shaped apical end of the metasomal horn. This species has been recorded as parasitising the eggs of an undescribed species of *Clubiona* (Clubionidae) inhabiting bark of eucalypt trees in the Australian Capital Territory. *C. platycornutus* is very similar to *cuspicornutus* and *longicornutus*, but differs in the shape of the metasoma horn (see comments under *cuspicornutus*).

Non-type specimens examined: AUSTRALIAN CAPITAL TERRITORY: 4♂, 11♀, University campus, Canberra, 10.i.1980, A.D.A., ANIC.

Ceratobaeus ricki sp. nov.

FIGS 30, 35, 39

Types: holotype ♀, ANIC, New South Wales: 10 mi E. Trangie, 20.x.1949, E. F. Rick; Paratypes 1♀, gold coated on SEM holder (mesosoma missing), wings on slide, 1♀ dissected on slide, 13♀, ANIC; same data as holotype.

Female

Length 2.1–2.3 mm. Colour. Head and mesosoma black; antennae dark brown; legs brown; metasoma dark brown to black. Head. L:W:H (7:20:14.5), with granulate sculpturing covered with short hairs; dorsally, slightly wider than mesosoma; occiput excavated and arched around pronotum; occipital carina sharp, not angled at corners; eyes large and hairless; lateral ocelli touching inner margins of eyes; frons slightly arched; anteriorly, head subtriangular; occiput slightly depressed medially; eyes separated by slightly more than 0.5 × width of head; frons smooth; frontal carina not developed; laterally, gena with margins parallel; antenna (fig. 39), club large with 3 faint incomplete sutures.

Mesosoma strongly compressed anterioposteriorly, posterior surface sloping towards metasoma; dorsally, with punctate-granulate sculpturing, covered with short hairs; pronotum not visible; scutum 2 × wider than long, L:W

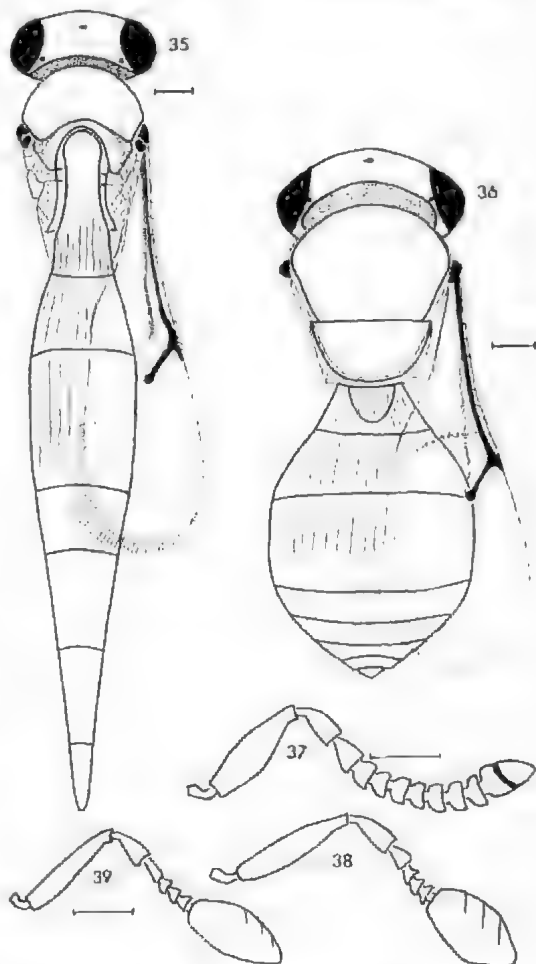


Fig. 35. *Ceratobaeus ricki*, ♀, dorsal surface of whole body. Fig. 36. *C. setosus*, ♀, dorsal surface of whole body. Figs 37–39. Antennae. 37. *C. setosus*, ♂. 38. *C. setosus*, ♀. 39. *C. ricki*, ♀. Scale lines = 100 µm. N.B. hairs and cilia not drawn on antennae and wings.

(8:16); notauli absent; scutellum transverse, L:W (1:10) with posterior fringe of long hairs; scutellum, metanotum and propodeum strongly excavated posteriorly for reception of horn; propodeal laminae vertical, without teeth dorsally (figs. 30 and 35).

Forewings fairly narrow, L:W (47:16), not reaching past T4, not infuscated; venation distinct, marginal and postmarginal veins

short, stigmal vein long, basal vein present but faint; marginal fringe of hairs moderately long (fig. 35).

Metasoma extremely elongated, approximately 4 \times longer than head and mesosoma combined, 6 \times longer than wide, L:W (90:15), covered with short hairs; horn long, strongly arched anteriorly, cylindrical but slightly flattened apically (fig. 30); T1-T3 including basal half of horn with longitudinal striations; lateral margins of T2-T3, and all T4-T7 with granulate sculpturing.

Male unknown.

Host unknown.

Non-type specimens examined: QUEENSLAND: Brisbane, Indooroopilly, 14.xii.76, Bouček, BMNH.

Comments

This species is named after its collector, Dr E. F. Rick. *C. rieki* is the largest species of *Ceratobaeus* so far recorded in the world; its elongate metasoma being unlike that of any other species.

Ceratobaeus setosus Dodd

FIGS 31-34, 36-38

Ceratobaeus setosus Dodd 1914a, p. 65; Kieffer 1926, p. 142; Auslin 1981, p. 85.

Types: holotype ♀, head and wings on slide, No. 1966, SAM; Queensland, Gordonvale (Nelson), 29.x.1913. A. P. Dodd.

Female

Length 1.3-1.5 mm. Colour. Head and mesosoma black; antennae and legs brown to dark brown; dorsal metasoma dark brown to black, ventral surface dark brown.

Head, L:W:H (8.5:19:15), with granulate sculpturing, covered with dense mat of short hairs; dorsally squarish, slightly wider than mesosoma, not strongly excavated posteriorly; occipital carina sharp, not angled at corners; eyes large, covered with hairs; lateral ocelli touching inner margins of eyes; frons almost straight; anteriorly, head subtriangular in shape; occiput arched; eyes separated by more than 0.5 \times width of head; frons smooth and shiny; frontal carina very short; laterally, gena with margins converging, rounded ventrally (fig. 31); antenna (fig. 38), club with 3 faint incomplete sutures.

Mesosoma. Dorsally slightly arched, with granulate sculpturing, covered with dense mat of short hairs (fig. 32); pronotum not visible at anterior lateral corners; scutum not much

wider than long, L:W (11:14.5); notauli absent; scutellum semicircular, L:W (5:11), with crenulated posterior border (fig. 36); metanotum narrow and crenulated; posterior surface of propodeum vertical; laminae diverging slightly, extended into 2 small sharply pointed teeth dorsally (fig. 33); laterally, mesosoma smooth and shiny.

Forewings just reaching posterior margin of metasoma, L:W (38:15.5); marginal and postmarginal veins short, stigmal vein long, basal vein dark; marginal fringe of hairs short (fig. 36).

Metasoma broad and flat, wider than mesosoma, pointed posteriorly, L:W (30:19) (fig. 36), covered with dense mat of short hairs; horn vertical, just reaching to level of scutellum, with reticulate-rugose sculpturing apically (fig. 33); base of T1-T3 with longitudinal striations; lateral margins of T2-T3 and all T4-T6 with granulate sculpturing.

Male

Differing from female in the following: length 1.2-1.3 mm; antennae and legs light brown; metasoma dark brown; antenna (fig. 37); posterior mesosoma almost identical, except propodeal laminae diverging slightly more than in female; forewings long, reaching well past posterior metasoma, L:W (42:16); metasoma broad, slightly wider than mesosoma, rounded posteriorly, L:W (24:18); anterior T1 expanded dorsally into hump, not reaching above propodeum, longitudinal striations reaching to anterior margin (fig. 34); T2-T6 with long scattered hairs.

Comments

C. setosus has been recorded along the coast of Queensland and New South Wales. In New South Wales this species has been reared from the eggs of *Ixentius robustus* (L. Koch) and *I. maritimus* (Simon) (Amauriidae), collected from around buildings and under bark of eucalypt trees. Another scellionid, *Ildris ixentii* (Hickman), has also been recorded as parasitising the eggs of these two spiders in Tasmania, Victoria, inland New South Wales and South Australia (Hickman 1967; Austin unpubl.). *C. setosus* can be easily recognised from all other species by its dense pilosity and sculpturing on the metasoma horn.

Non-type specimens examined: NEW SOUTH WALES: 1♂, 3♀, gold coated on SEM holders, wings and antennae of 1♂, 1♀ on slides, 1♀ dissected on slide, 4♂, 21♀, 'ANR', 3 A, 17, 'CNC'.

Pearl Beach, Jan. 1976, A.D.A., ex eggs *Ixentius robustus* (L. Koch) (Araneae); 1♂, 5♀, SAM; 1♂, 5♀, WAITE, Caringbah, 12.iii.1976, A.D.A.; 3♀, Pearl Beach, Jan. 1978, A.D.A., BMNH; 2♂, 4♀, Caringbah, 22.iii.1976, A.D.A., QDPI. QUEENSLAND: 1♀, Brisbane, Sept. 1928, A. D. Dodd; 1♀, Gogango, Dec. 1928, A. P. Dodd; 1♀, Gordonvale, Nov. 1920 (no collector), ANIC; 2♂, 2♀, Maleny, 14.vi.1973, M. D. (D.A.I.); 1♀, 600-700 m Sunday Creek nr Limna, 28-29.ix. 1974, I. Naumann, QDPI.

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SOME NEPOMORPHA (CORIXIDAE, NOTONECTIDAE AND NEPIDAE) (HEMIPTERA-HETEROPTERA) OF NORTH-WEST AUSTRALIA

BY I. LANSBURY

Summary

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Summary

LANSBURY, I. (1984) Nepomorpha (Corixidae, Notonectidae and Nepidae) (Hemiptera-Heteroptera) of North-West Australia. *Trans. R. Soc. S. Aust.* **108**(1), 35-49, 12 June, 1984.

New taxa of Notonectidae, viz. *Walambienisops wandjina* n.gen. and sp., *Enithares gwini* n.sp., *Anisops douglasi* n.sp., and Corixidae, viz. *Agraptocorixa gambrei* n.sp. are described from the coastal region of the Kimberley, north-west Australia. Brief notes are given on the water-bugs of the Kimberley vis-à-vis those of the coastal zone, the Arnhemland Escarpment, and northern Queensland. A key to the Australian genera of Notonectidae, including new genera, is given, as well as a supplementary key to the Anisopinae using a combination of secondary sexual characters.

KEY WORDS: Corixidae, *Agraptocorixa*, Notonectidae, *Anisops*, *Enithares*, *Paranisops*, *Walambienisops*, zoogeography.

Introduction

Williams (1979) gives a concise description of north-western Australian freshwater fauna and a list of the water bugs recorded. Most of the species he listed are characteristically Australian, although some, according to the data given, were collected from habitats east of the Kimberley in the Northern Territory. The Kimberley data available to Williams supported his view that north-western Australia including the Kimberley is not a distinct fluvi-faunal province, but some more recent data derived from collections in the coastal region shed additional light on the biogeographical relationships of water-bugs in this area. They show that the water-bug fauna of the coastal region is unusual in having at least one link with Timor and Lombok, and is clearly not allied to the characteristic Australian fauna which extends eastwards to New Caledonia and the New Hebrides—as typified by the *Enithares woodwardi* Lansbury complex of sibling species (*bergrothi* Kirkaldy and *hebridensis* Lansbury). The new data suggest that species groups common to north-western Australia and Timor-Lombok have not in general become widespread over Australia.

There is some evidence that a few species of water-bugs are distributed along the tropical fringe from north-west Australia, through the Northern Territory to north Queensland. The lack of data precludes a realistic discussion of the zoogeography of the north-west coastal region compared with areas of the Northern

Territory and Queensland; so many groups of water-bugs, i.e. Veliidae, Gerridae, Notonectidae (*Anisops*), Corixidae (*Microneecta*) and Hydrometridae, are insufficiently known from the north west coastal region. A few general comments are given on the relationships of the taxa of the north-west with other areas of "northern" Australia and elsewhere under species descriptions.

Family: CORIXIDAE

Agraptocorixa gambrei sp. nov.

FIGS. 1-12

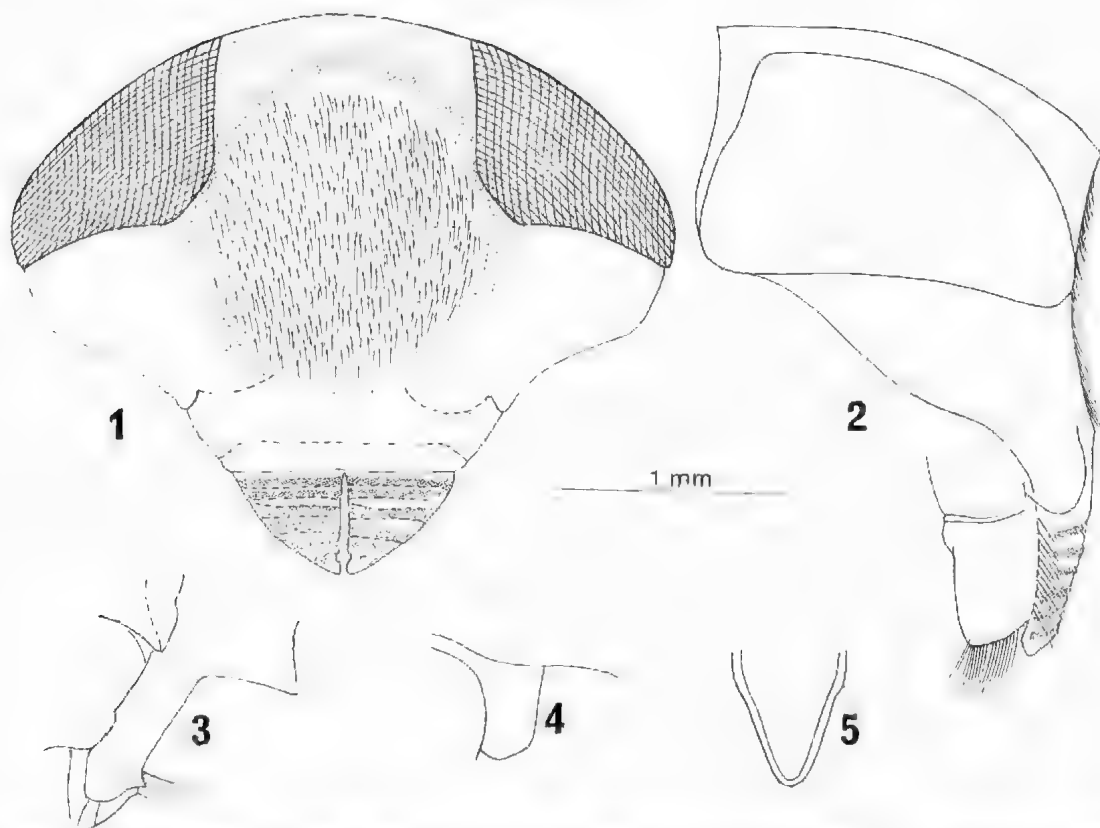
Holotype: Male, WAM 79-294-317. W.A., Port Warrender, ix.1976, A. M. Douglas in the Western Australian Museum, Perth.

Dimension of holotype: Length, 7.75 mm, width across the eyes, 2.8 mm.

Colour: Vertex pale yellow, posterior margin dark brown. Pronotum dark brown. Clavus yellowish brown with inner lateral anterior and posterior angles dark brown. Corium yellowish brown with a large dark brown area along posterior half of the claval suture, the infuscated area almost reaching the embolium. Membrane heavily infuscated. Embolium dark reddish brown becoming paler distally. Thorax ventrally pale yellow, abdomen slightly darker. Front legs yellow, area of pala claws dark brown. Middle femur pale yellow, distal third and remainder of leg dark brown. Hind femur pale yellow, tibia and tarsi rather darker.

Structure: Vertex rounded and slightly produced between the eyes. Interocular space (synthipsis or narrowest part between the eyes) less than an eye's width 1.3:1.4. Head length to pronotal length .75:1.00. Facial im-

² Hope Entomological Collections, University Museum, Oxford, U.K.



Figs 1-5: *Agraptocorixa gambrei* sp. nov. holotype male. (1) head from the front; (2) *ibid.* side view; (3) osteole of scent gland; (4) lateral lobe of prothorax; (5) metaxyphus.

pression conspicuous (Figs 1, 2), clothed with fine silvery hairs, impression extending from lower margin of eyes almost to transverse sulcations. Pronotal width twice median length, covered with fine dark brown adpressed spines arising from black bases. Clavus with similar spines about twice as long as those on the pronotum. Corium and right membrane clothed in longer dark brown hairs. Left membrane with sparse scattered short hairs. Pruinoso area of the claval suture one third length of corial pruinose area 34:100. Post-nodal pruinose area length about half width 4:10. Lateral lobe of the prothorax as in Fig. 4. Metaxyphus as in Fig. 5. Sixth-eighth tergites as in Figs 6-8. Sixth tergite with an extension, no "strigil" visible. Front leg (Fig. 9) femur with several stout spines, pala with fifteen pegs, claws conspicuous. Middle femur curved, almost quadrate in section, inner margin densely clothed with fine silvery hairs. Hind femur (Fig. 10) anteriorly pubescent. The relative lengths of legs are shown in

Table 1. *Male genitalia* (Figs 11, 12); right clasper elongate wedge-shaped, left clasper long and thin.

Comparative Notes

It is not possible to key out *A. gambrei* in Knowles (1974) as the species does not have a strigil. The sixth tergite has a projection rather like that of *A. parvipunctata* (Hale), *A. halei* Hungerford, and *A. hyalinipennis* (Fabricius), the latter does not occur in Australia, but there is no comb-like structure present. The number of pala pegs eliminates *A. parvipunctata* and *A. halei*, as both have at most twelve pala pegs, the right claspers of both are quite distinctive, and the *hyalinipennis* males have

TABLE 1. *Relative lengths of legs for Agraptocorixa gambrei* sp. nov.

	Femur	Tibia	Pala	Claw
Front leg	100	44	80	25
Middle leg	100	46	29	29
Hind leg	100	103	113	40



Figs 6-8: *Agraptocorixa gambrelli* sp. nov., holotype male. (6-8) tergites 6-8.

the face flattened but not depressed and the peg row is much longer (22+), extending two thirds the length of the pala palm. The facial depression of *A. gambrelli* is clearly concave and well-defined, the peg row short not reaching half way across the palm.

There are now six species of *Agraptocorixa* known from Australia. Of these, *A. halei*, *A. parvipunctata*, *A. hirtifrons* (Hale) and *A. gambrelli* sp. n. appear to be endemic, while *A. eurynome* Kirkaldy and *A. macrops* Hungerford are also known from New Guinea (Jansson 1982). *A. parvipunctata* and *A. eurynome* are both widespread species occurring over most of Australia and Tasmania; *A. hirtifrons* occurs sporadically, and *A. halei* seems to be a rather more tropical element, occurring in north-west Australia, the N.T. and northern Qld. Knowles (1974) provides records for N.S.W. and Alice Springs. *A. macrops* is known from New Guinea and Bunbury, W.A. *A. gambrelli* is known only from the coastal region of the Kimberley district.

Agraptocorixa halei Hungerford
FIGS 13-19

Agraptocorixa halei Hungerford, 1953, pp. 42-44.

Agraptocorixa halei: Knowles, 1974, pp. 181-183, figs 25-32.

Hungerford (1935) and Knowles (1974) have described and figured *A. halei* extensively. However, the form from Mt Trafalgar differs in some minor details from the typical form. The claw of the front leg is large but almost transparent in the "prepared" state (Fig. 13). The strigil is rather larger, almost horseshoe-shaped with five combs (Figs 15, 16) rather than three as described previously. Earlier figures of the 7th tergite show what appears to be a "free" triangular lobe dextrally; however, the posterior margin of the 7th tergite is continuous, and there is a narrow, lightly sclerotised strip which superficially resembles a complete break in the tergite (shown as a pair of dotted lines on Fig. 14). Knowles' figure of the left clasper is drawn from an unusual angle; the clasper is broad with a prominent finger-like projection at its base (Fig. 17). The right clasper is much like previous illustrations (Fig. 18). The tip of the aedeagus is as shown (Fig. 19).

Material examined: W.A. Prince Regent River Reserve, Mt. Trafalgar, 15°75'S, 125°04'E, 26.viii.1974, W. J. Bailey & K. T. Richards, one male and one female (Department of Agriculture, Perth, W.A.).

Family: NOTONECTIDAE

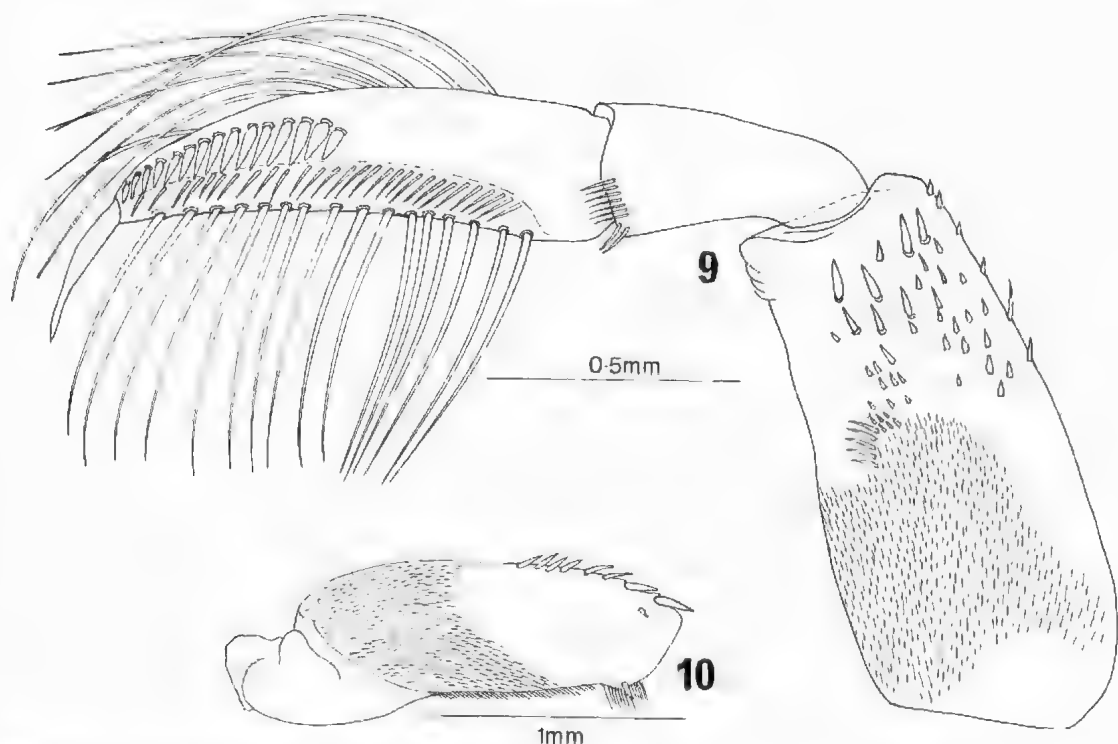
Anisops douglasi sp. nov.

FIGS 20-22

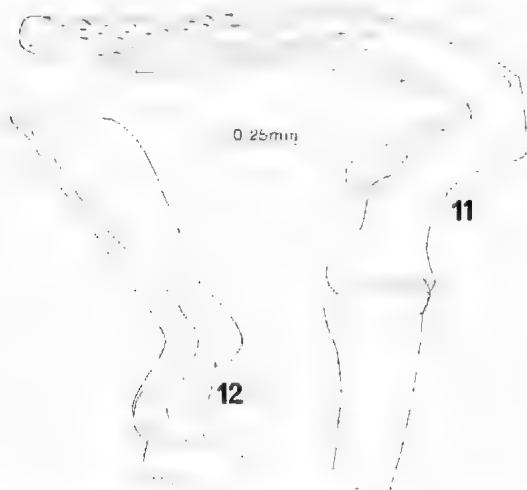
Holotype male: WAM 79-294-317, W.A., Kimberley region, Port Warrender, ix.1976, A. M. Douglas; in the Western Australian Museum, Perth. Dimensions of holotype: Length 6.9 mm.

Colour, ethanol specimen: Eyes grey with facets black. Pronotum anteriorly hyaline grey, posteriorly faintly tinged with orange. Scutellum creamy yellow. Elytra hyaline, appearing grey with dorsal coloration showing through. Abdomen brown, ventrally rather darker with intersegmental membranes pale yellow. Connexivum pale yellow tinged with orange.

Structure: Viewed dorsally the head is broadly rounded with the anterior inner lateral margins of the eyes convergent. Greatest width of head fractionally less than pronotal humeral width, about ten times, anterior width of the vertex, and almost three times the median head length. Synthipsis wide, over half but



Figs 9-10: *Agraptocorixa gambrei* sp. nov. holotype male. (9) front leg; (10) hind femur.



Figs 11-12: *Agraptocorixa gambrei* sp. nov. holotype male. (11) left clasper; (12) right clasper.

less than two-thirds the anterior width of the vertex. Median pronotal length about one third longer than the head. Pronotal humeral width just over twice median length, lateral margins straight, slightly divergent over half median length. Facial tubercle enlarged with small stiff hairs (Fig. 21). Rostral prong large,

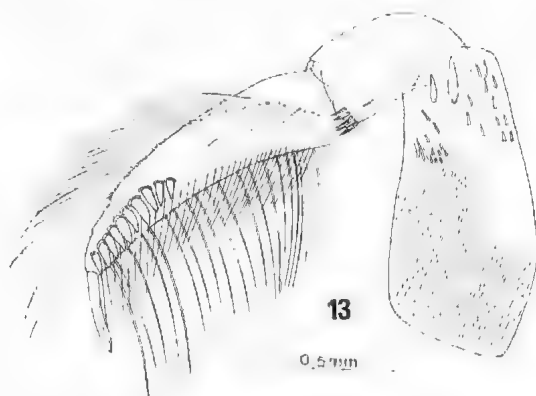
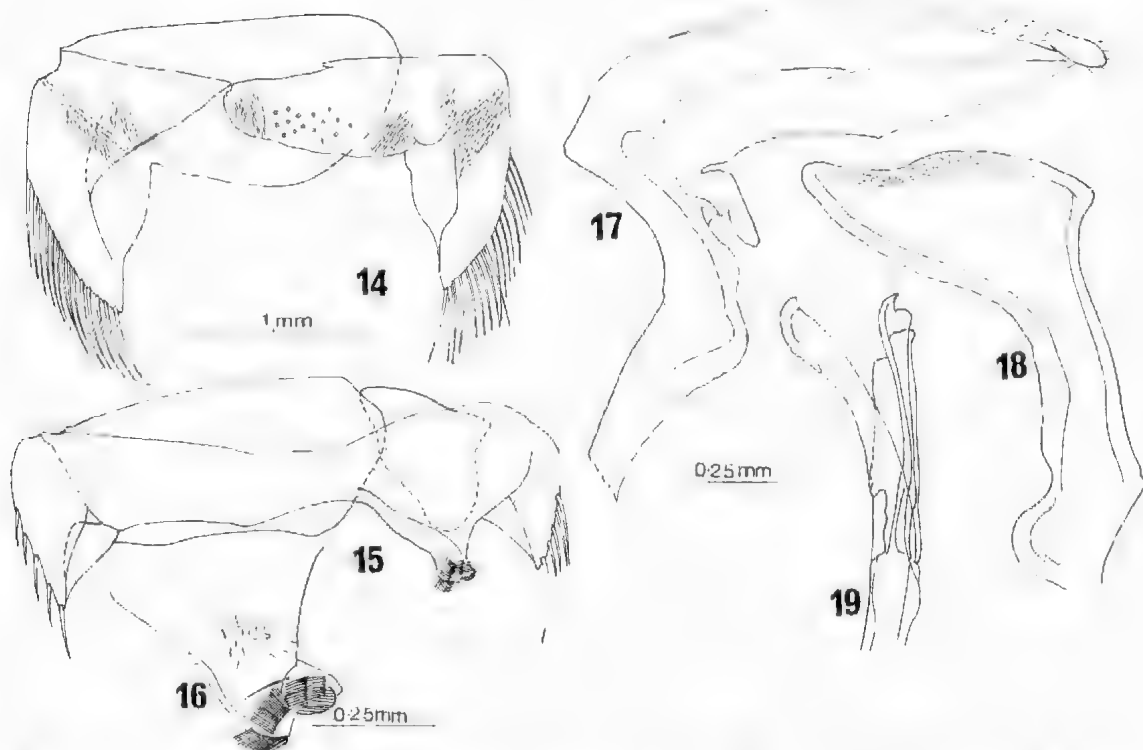


Fig. 13: *Agraptocorixa halei* Hungerford male. (13) front leg.

the tip almost reaching the anniferous tubercle. Labrum slightly broader than long, apex acuminate. Stridulatory comb with twelve pegs, outer seven rather longer (Fig. 22). Chaetotaxy of the front leg as shown (Fig. 20).

Comparative notes

This species keys out to *A. doris* Kirkaldy in Lansbury (1969). However, the large rostral prong, enlarged facial tubercle, and small



Figs 14–19: *Agraptocorixa halci* Hungerford male. (14) 6th tergite; (15) 7th tergite; (16) strigil; (17) left clasper; (18) right clasper; (19) tip of aedeagus.

stridulatory comb distinguishes *A. douglasi* from *A. doris*. In Brooks' (1951) key, *A. douglasi* appears to be closely allied to *A. assimilis* White, a New Zealand species, but the latter does not have an enlarged facial tubercle, and the stridulatory comb has about 25–28 pegs (*A. douglasi* has rather fewer). Young (1962) redescribed *A. assimilis* and showed that Brooks' description of the stridulatory comb was misleading, for the pegs decrease in size gradually towards the inner margin of the front tibia; the "steps" figured by Brooks is due to some of the pegs having been broken.

Anisops occipitalis Breddin
FIGS 23–25

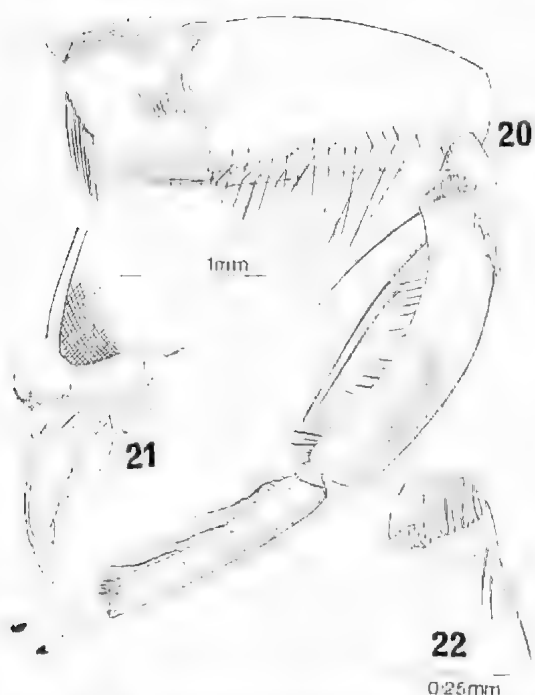
Anisops occipitalis Breddin, 1905, p. 152.

Anisops occipitalis: Brooks, 1951, pp. 344–5, Pl. 39, fig. 22.

Anisops occipitalis: Lansbury, 1969, pp. 438–440, figs. 18–22. (*Anisops ocularis* Hale, 1923 synonymised with *occipitalis*).

The occurrence of *A. occipitalis* in mainland Australia is rather patchy. Under the

name "*ocularis*", Hale (1923) first described and recorded the species from Australia (Darwin). Brooks (1951) gives data for Sir Graham Moore Island, and the Barron River, Qld. I have collected material from Petersen Creek, Yungaburra near Atherton, Qld, which has been provisionally assigned to *A. occipitalis*. This species bears some resemblance to *A. deanei* Brooks. Both have prominent rostral prongs, and the apex of the third rostral segment is clearly wider than the base of the fourth (Fig. 23); both species have five spines on the inner surface of male front tibia (Fig. 24), and the number of stridulatory pegs is roughly the same (20–24). The front femur of *A. occipitalis* is most distinctive, being broad proximally with "steps" distally; *A. deanei* has the upper and lower margins of the femur more or less evenly curved. According to Brooks (1951) *A. deanei* males are at most 6 mm long, but I have found that this species is usually more than 6 mm long, with a maximum length of 6.75 mm (Lansbury 1969). Large collections of *A. deanei* from "southern" Australia made in 1979 show that *A. deanei*



Figs 20-22: *Anisops douglasi* sp. nov. holotype male. (20) front leg; (21) side view of rostrum; (22) stridulatory comb.

varies rather more in size than originally thought (Lansbury 1969). Extensive series from habitats around Alice Springs vary from 6.5-7.5 mm long. *A. occipitalis* varies sufficiently for smaller males of *A. occipitalis* to overlap with the *A. deanei* males. However, the little data there are suggests that *A. occipitalis* is a "coastal" species in Australia.

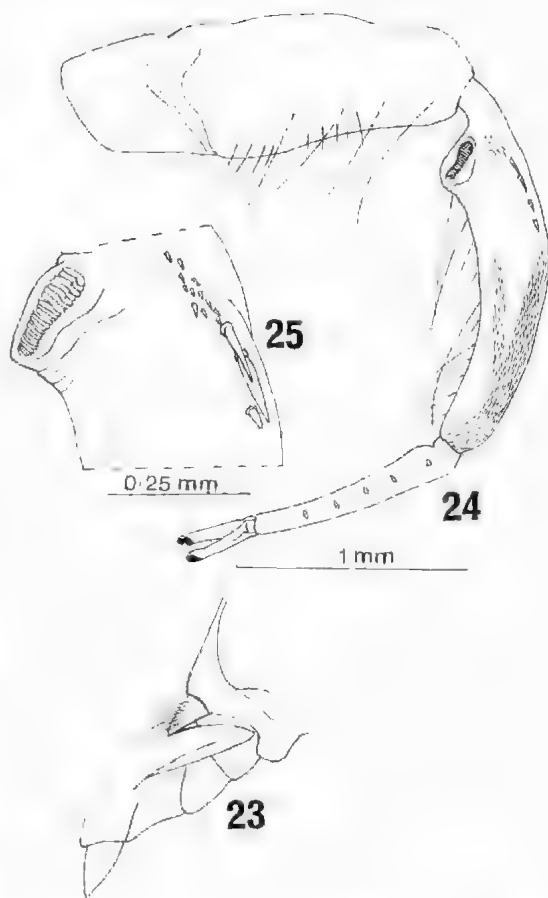
Material examined: Western Australia: WAM 75-163-9, Wotjulum Mission via Derby, October 1955, A. M. Douglas, two males and two females in the Western Australian Museum, Perth. N.W. Australia, Prince Regent River Reserve, Charnley River, 14.viii.1974, W. J. Bailey & K. Richards, one male in Department of Agriculture, Perth, W.A.

***Enithares gwini* sp. nov.**

FIGS 26-30, 33-36

Holotype male: WAM 79-294-317, two male and seven female paratypes, Western Australia, Port Warrender, Kimberley, October, 1976, A. M. Douglas. One male and female paratypes, WAM 79-218-27, Kalumhuru Mission, Kimberley, Western Australia, June, 1960, A. M. Douglas & G. Mees in Western Australian Museum, Perth.

Shape: Broad robust species, lateral margins of the body converging slightly about midway

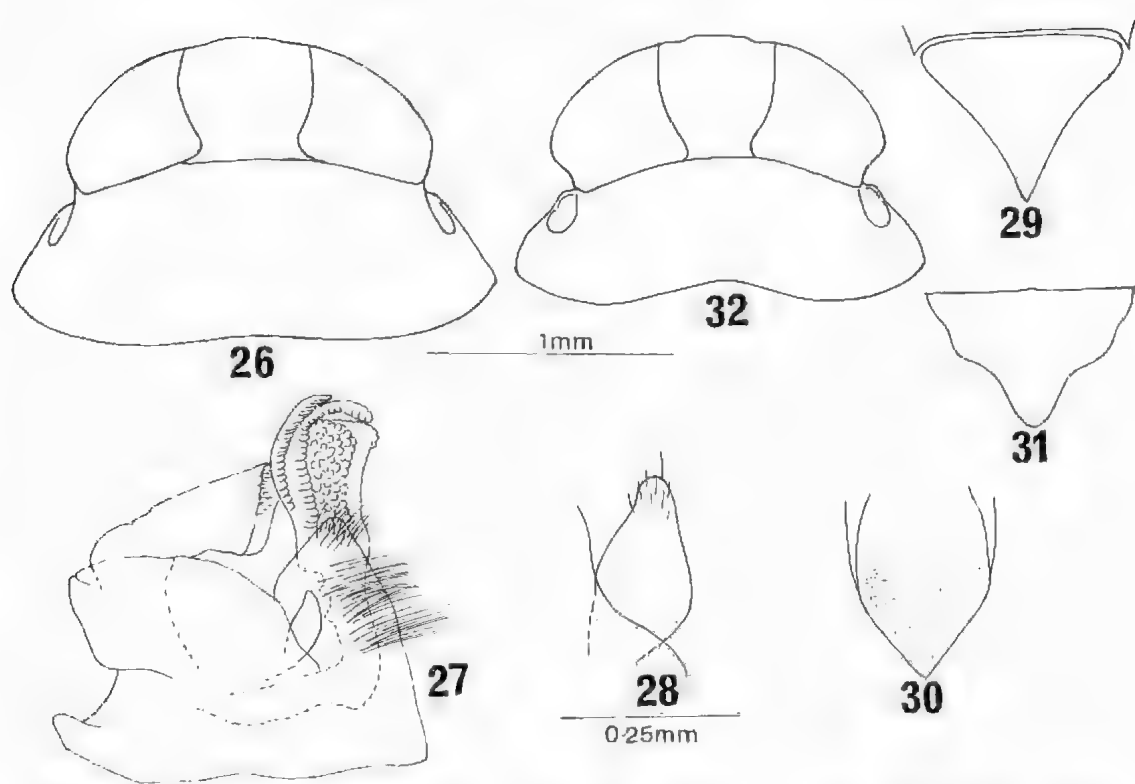


Figs 23-25: *Anisops occipitalis* Breddin male. (23) side view of rostrum; (24) front leg; (25) stridulatory comb.

body length, Median head length appearing to be rather short compared with body length (1:10).

Colour: Eyes brown. Vertex and anterior half of the pronotum straw yellow, viewed from the front, vertex with a brown bar between the eyes (not visible from above). Posterior half of the pronotum hyaline. Scutellum bluish-black, lateral margins yellow. Anterior angles of the clavus and corium yellow, pale coloration reaching the nodal furrow, remainder of clavus and corium rich brown to black in dry mounted specimens, colour in ethanol appearing rather darker with yellow areas rather more red than yellow. Membrane bluish-black. Embolium greyish yellow. Sternites black with central keel greyish yellow.

Structure: Head rounded, anterior width of the vertex more or less continuous with the



Figs 26–32: *Enithares* sp. males, *E. gwini* sp. nov. Figs 26–30: (26) head and pronotum dorsum; (27) genital capsule; (28) paramere enlarged; (29) labrum; (30) metaxyphus; *E. lombokensis* Lansbury. Figs 31–32: (31) labrum; (32) head and pronotum dorsum.

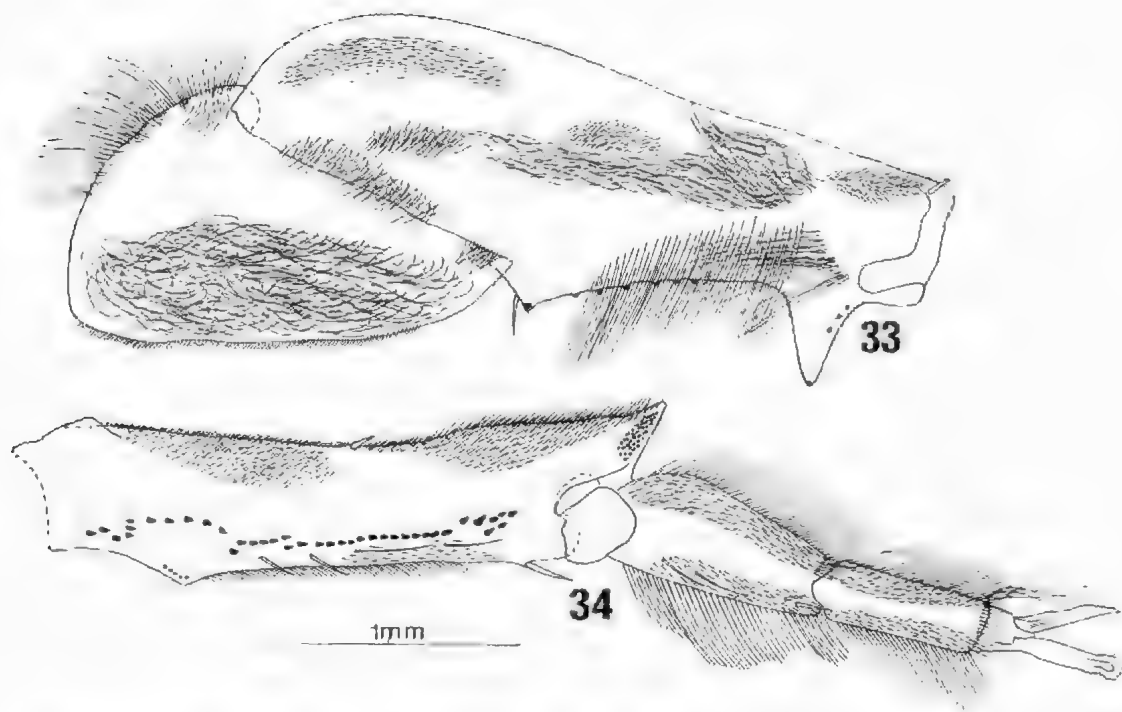
eyes. Greatest width of head about two thirds pronotal humeral width, just over two and a half times the anterior width of the vertex, and three times median head length. Synthipsis wide, just over half the anterior width of the vertex. Head length slightly less than the anterior width of vertex. Pronotal humeral width almost three times median length, lateral margins strongly divergent, appearing straight although they are slightly convex. Dorsal margin of pronotal fovea directed obliquely laterad behind the eyes (Fig. 16). Nodal furrow obliquely turned towards the head and less than its own length removed from the membranous suture. Labrum acutely triangular (Fig. 29). Mesotrochanter rounded densely clothed in long curly hairs, inner lower margin of middle femora densely hairy (Fig. 33). Of the middle tibia and tarsi (Fig. 34), the tibia is prolonged at outer distal margin, and the inner proximal margin has a less prominent projection. Hind femur of male produced distad-ventrally (Fig. 36). First tarsal segment of the hind leg with a ridge along the inner

margin fringed with long hairs along both margins (Fig. 35). Metaxyphus triangular (Fig. 30). Male genital capsule as illustrated (Fig. 27); parameres (claspers) symmetrical (Fig. 28).

Comparative notes

Similar to *Enithares lombokensis* Lansbury (Fig. 32) and *E. buhleri* Brooks, *E. gwini* is a more robust species. The front tibia of *E. gwini* is parallel sided, that of *E. buhleri* (Fig. 37) is distally conate, the front tibia of *E. lombokensis* (Fig. 39) deeply concave with a blunt projection distally. The middle tibia of *E. gwini* has a blunt projection apically, and is sharply produced distally whereas *E. buhleri* (Fig. 38) and *E. lombokensis* (Fig. 40) both have more or less parallel-sided mid-tibiae which are sharply produced distally.

Three other species of *Enithares* are known from Australia. *E. woodwardi* is widespread over much of "southern" Australia. *E. huckeri* Hungerford occurs sporadically in northern N.S.W. and Qld. The third species *E. loria*



Figs 33-34; *Enithares gwini* sp. nov. holotype male. Middle leg.

Brooks, originally described from New Guinea, is found fairly frequently along the tropical fringe of the N.T., Qld, and in the Solomon Islands (Lansbury 1968).

***Walambianisops wandjina* gen. and sp. nov.**

FIGS 41-57

Generic diagnosis: Vertex extending beyond the eyes. Antennae two-segmented. Labrum and rostrum conspicuously hairy. All legs of both sexes with two-segmented tarsi. Front coxa and femur long. Coxal plates (third episternum and infracoxal plates of Aucts.) bare, distally fringed with short black hairs. Fifth and sixth sternites carinate, narrowly bare, fringed with short black hairs.

Type species: *Walambianisops wandjina* sp. n.

In the discussion following the description of this new genus and species, a section is included on *Paranisops* which is a superficially similar genus. The merits of the latter as a generic entity are commented upon.

***Walambianisops wandjina* sp. nov.**

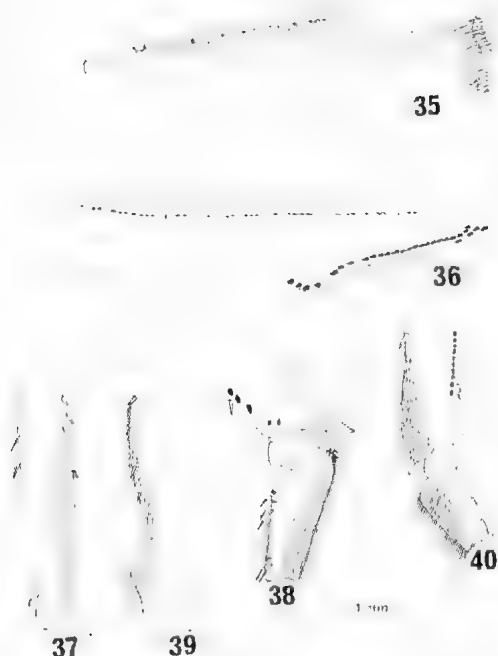
FIGS 41-57

Type series: Holotype male, seven male and six female paratypes WAM 79-287-93 and WAM 79-294-317 W.A., Port Warrender, Kimberley,

ix.1976, A. M. Douglas; two male and three female paratypes WAM 79-218-27 W.A., Kalumburn Mission, Kimberley, vi.1960, A. M. Douglas & G. Mees; one female paratype WAM 79-165-9 W.A., Wotjulum Mission via Derby, Kimberley, ix.1955, A. M. Douglas in the Western Australian Museum, Perth. One male and one female paratypes, N.W. Australia, Prince Regent River Reserve, 17°07'S, 125°33'E ex ravine pond, 17.viii.1974, W. J. Bailey & K. T. Richards, in the Department of Agriculture, Perth, W.A. One female paratype, W.A., Koolan Island, permanent pool in dry creek bed, 13.ii.1978, W. D. Williams in the collections of Adelaide University.

Length: males 9-9.6 mm, females 9-9.9 mm.

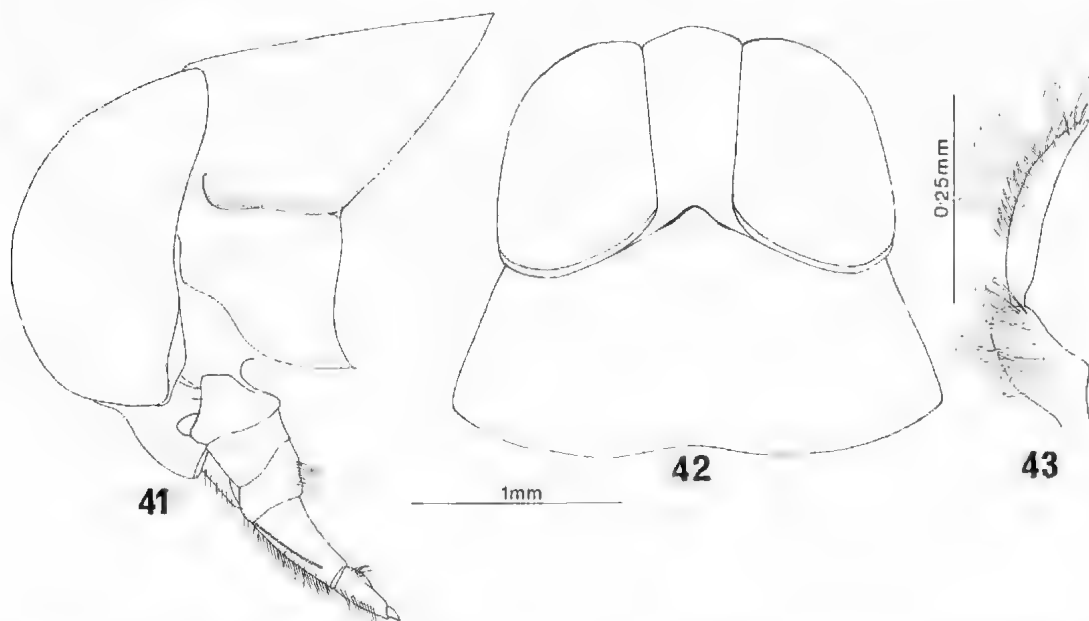
Colour: Eyes either greyish with pale horizontal bands or dark reddish brown. Head yellow with a small brown spot between the eyes on the frons. Pronotum anteriorly greyish brown, posteriorly more hyaline, appearing darker due to dorsal coloration showing through. Scutellum dark brown to black, shining, apex and part of the lateral margins orange yellow. Clavus and corium apically suffused dark brown to black, occasionally the dark suffusion extending over most of the clavus and along the outer lateral margin of the corium, both the clavus and



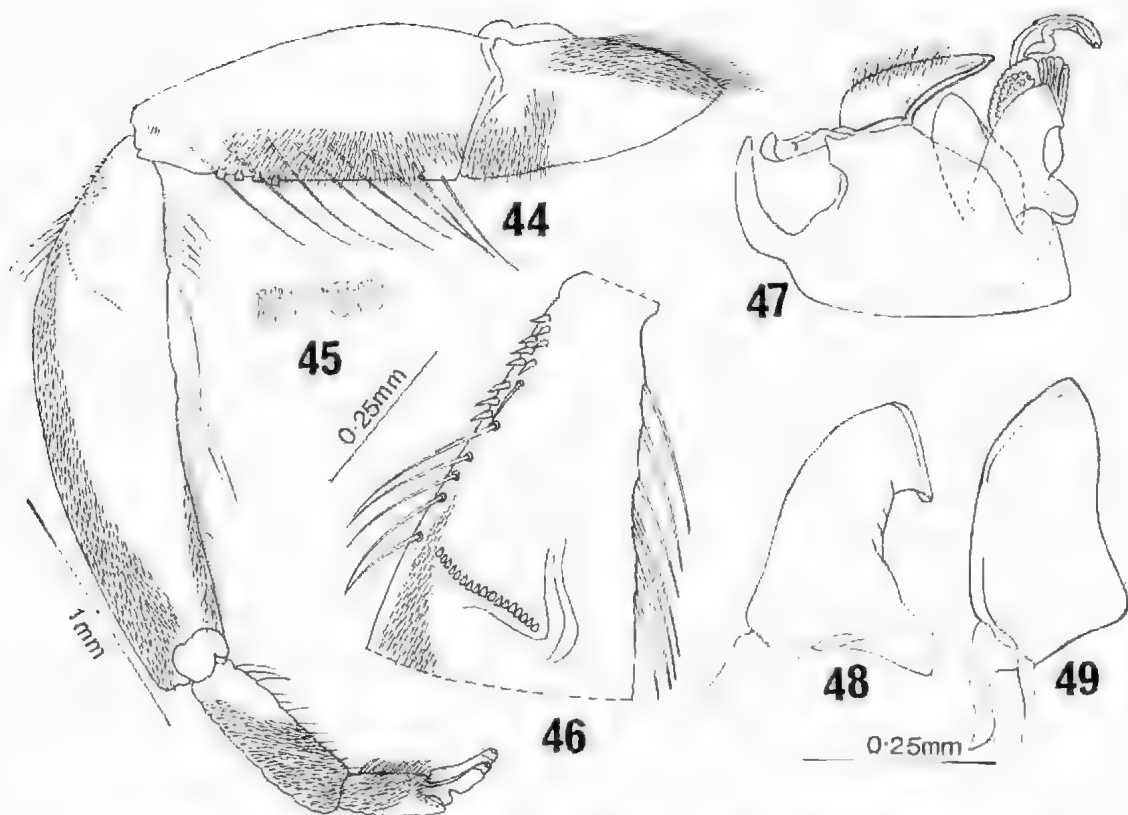
Figs 35-40: *Enithares* sp. males, *E. gwini* sp. nov. Figs 35-36: (35) first tarsus of hind leg; (36) hind femur distally; *E. bühleri* Brooks. Figs 37-38, *E. lombokensis*. Figs 39-40: (37 & 39) front tibia; (38, 40) distal end of middle tibia and 1st tarsal segment.

corium faintly iridescent green. Remainder of the elytra and membrane hyaline, the reddish brown tergites showing through. Legs dark-reddish brown with margins narrowly yellow, particularly conspicuous on the front and middle legs. Thorax reddish-brown with yellow patches. Sternites dark brown to bluish black. Lateral margins of the connexivum narrowly pale yellow.

Structure: Eyes large and protuberant, vertex extending beyond the eyes (Fig. 42), dorsally between the eyes shallowly depressed. Facial tubercle enlarged and rounded, frons above facial tubercle deeply concave. Labrum and rostrum hairy, labrum slightly broader than long. Anterior lateral margin of the third rostral segment finely serrate (Fig. 41). Greatest width of head five times anterior width of vertex, and about six times width of the synthlipsis which is almost as wide as the anterior width of the vertex. Head width more than twice median head length. Anterior margin of pronotum raised and produced between the eyes. Pronotum almost one and a half times longer than the head, humeral width greater than head width and almost twice the median pronotal length, lateral margins strongly divergent. The female is much like the male, head width three times head length,



Figs 41-43: *Walambianisops wandjina* gen. and sp. nov. male. (41) head and pronotum from the side; (42) *ibid.*, dorsum; (43) antennae.



Figs 44-49: *Halammbianisops wandjina* gen. and sp. nov. male. (44) front leg; (45) enlarged detail of front leg; (46) enlarged detail of front tibia; (47) genital capsule; (48, 49) right and left parameres.

pronotum almost twice as long as the head. Scutellum large, strongly convex, about as broad as long.

Front coxa and femur longer than tibia, front tarsi two segmented, claws short and blunt apically, those of the female spinose. Femur with four groups of elongate setae arranged like inverted cones (Figs 44, 45). Front tibia moderately spinose with a row of "pegs" separate from each other forming a "stridulatory-comb" (Fig. 46). Middle femur elongate and spinose, chaetotaxy not differing greatly from that of front leg, but without the peg-row. Very little difference between chaetotaxy of males and females. Hind leg elongate, fringed with moderately long swimming hairs, tarsi of middle and hind legs two-segmented.

Coxal plates bare and shining with coarse irregular oblique striations, distally fringed with black hairs (Fig. 51). Third sternite just visible latero-distad of coxal plate. Fourth sternite with a trichome, fifth-seventh sternites variably carinate, apically narrowly bare, fringed with

short black hairs. Female seventh sternite not as acutely carinate as preceding sternites, males rather more sharply convex than carinate. Outer lateral margins of connexival segments two-four with small half-moon shaped projections arising from depressions in the integument (Fig. 51). Arising from the lateral margins of the seventh and eighth tergites pale yellowish hairs which are much longer than those along the inner margins of the connexivum. Male seventh abdominal tergite with a prominent sclerotised spine on the caudo-sinistral margin (Figs. 53, 54). Male operculum (subgenital plate) with fringes of hairs distally (Fig. 57). Female operculum much larger, deeply convex and fringed with several rows of hairs and spines (Figs 55, 56).

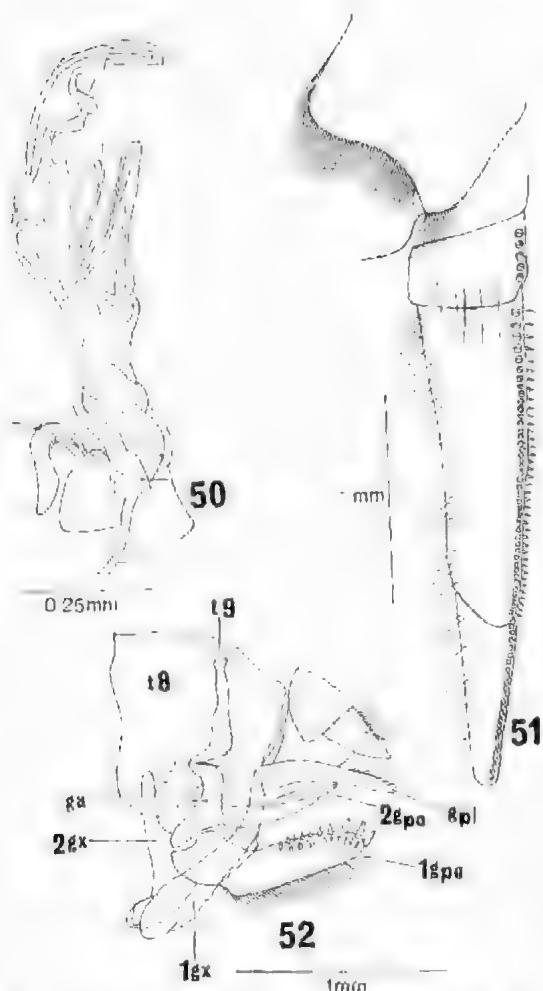
Antennae two-segmented, both segments with modified spatulate hairs (Fig. 43).

Male genitalia (Fig. 47): capsule partially cleft posteriorly and heavily sclerotised, para-

Discussion

Superficially, *Walambianisops* resembles *Paranisops endymion* (Kirkaldy). However, despite resemblance in size and coloration, only one primary character is common to both genera: all legs of both sexes have two-segmented tarsi. *Walambianisops* has many features in common with *Anisops*, but the operculum is not sharply carinate as it is in *Anisops*; it is variably convex, i.e. it is structurally midway between *Anisops* and *Paranisops*. The males of *Walambianisops* have a large sclerotised spine on the seventh tergite (Figs 53, 54); *Anisops* and *Buenoa* Kirkaldy (New World counterpart of *Anisops*) have a variously shaped projection on the same tergite. This projection is absent from *Paranisops* species (Figs 58–60). The seventh abdominal tergite of *Walambianisops* is asymmetrical, that of *Paranisops* symmetrical with a prominent sclerotised projection extending caudad dorsally (Figs 58–61). The eighth abdominal segment is much the same in both genera. The male genitalia of *Paranisops* (Fig. 62) are robust, well-sclerotised structures, cleft posteriorly. The parameres of *P. endymion* are symmetrical, of *P. inconstans* Hale, asymmetrical; those of *Walambianisops* are much like the generalised type found in *Anisops* and *Buenoa*. The first gonapophysis of *Anisops*, *Buenoa* and *Walambianisops* are all heavily sclerotised and spinose, whereas *Paranisops* has a feebly sclerotised first gonapophysis which are plate-like with a few spines distally.

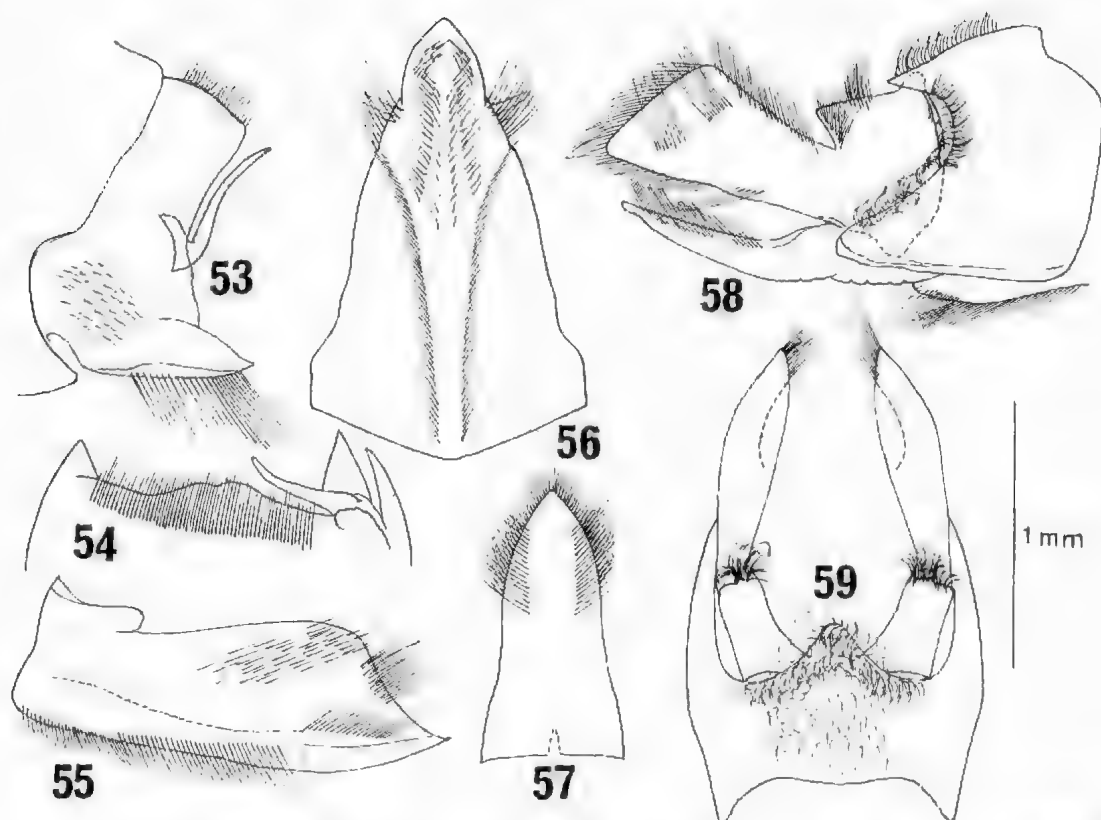
Features unique to *Walambianisops* males include the four groups of setae on the front femur and the row of pegs across the front tibia. (The latter are homologous with the more complex stridulatory peg row of *Anisops* and *Buenoa*. The row of serrations along the third rostral segment of *Walambianisops* can be equated with the rostral prong of related genera.) Finally, there is a series of half-moon shaped projections on the outer lateral margins of the connexivum. Female *Walambianisops* can be distinguished from *Paranisops* by the smooth coxal plates; in *Paranisops* these plates are covered in black hairs. Females of *Walambianisops* may be distinguished from *Anisops* by their two-segmented antennae (those of *Anisops* are always three-segmented). Although the antennae of *Walambianisops* are two-segmented, the general chaetotaxy closely resembles that of *Anisops* (Lundblad 1933).



Figs 50–52: *Walambianisops wandjina* gen. and sp. nov. (50) male aedeagus; (51) coxal plates and connexivum of male; (52) female genitalia: terminology 8–9 paratergites 8 & 9, 1 & 2 gpo 1st and 2nd gonapophysis, 1 & 2 gx 1st and 2nd gonocoxa, ga gonangulum, gpl gonoplac.

meres (claspers) large and asymmetrical (Figs 48, 49), aedeagus membranous (Fig. 52).

Female genitalia (Fig. 52): first gonocoxa elongate, anterior margin infolded forming a partial ramus. First gonapophysis large, sclerotised with stout spines distally, ventrally fringed with short hairs. Gonangulum elongate, almost reniform, fused to paratergite nine. Second gonocoxa membranous and acutely triangular. Second gonapophysis membranous, distally lightly sclerotised. Gonoplace stylus-like with scattered hairs.



Figs 53-59: *Walambianisops wandlini* gen. and sp. nov. Figs 53-57: (53) male 7th tergite side view; (54) *ibid.*, dorsum; (55) side view of female operculum; (56) *ibid.*, ventrally; (57) male operculum ventrally; *Paranisops incynatus* Hale male. Figs 58-59: side and dorsal aspects of 7th and 8th tergites.

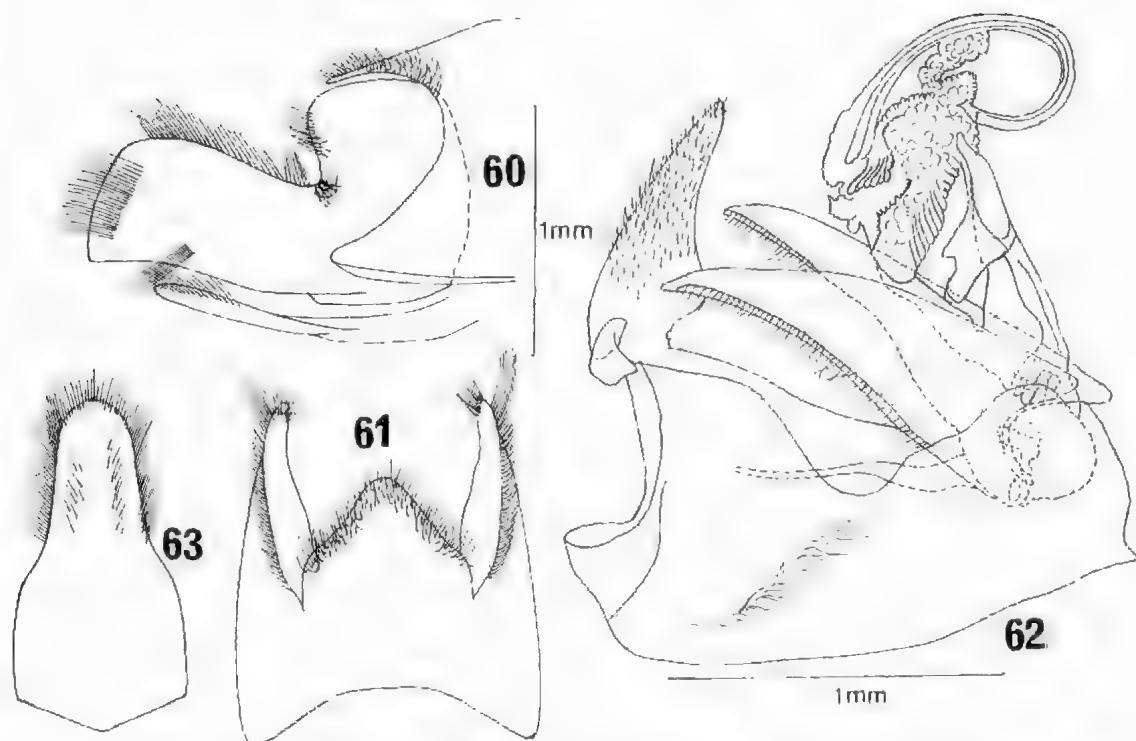
Walambianisops shares a number of features with *Anisops* and *Paranisops*. However, the combination of characters found in *Walambianisops* supports the hypothesis that *Anisops*, *Buenoa* and *Walambianisops* are more closely related to each other than they are to *Paranisops*. The key to the Australian genera of Notonectidae reflects the close relationship of *Walambianisops* and *Anisops*. However, if secondary sexual characters are used, as in the alternative key to the Anisopinae, *Walambianisops* is shown to be quite distinct from other genera of the subfamily.

Anisops, itself is a large genus with ca. 30 species known from Australia (well over 100 in the Old World). One species, *A. agalia* Hutchinson from South Africa, was placed in a separate subgenus *Anisopoides* as the males lack a rostral prong, the stridulatory pegs are arranged in the same way as in *Walambianisops*, the front tibia is enlarged apically (those of *Walambianisops* are not).

Anisops agalia males, like all other species in the genus, have one-segmented front tarsus. No information is available on the presence of discrete auditory specialisations on the rostrum.

Buenoa males have two-segmented front tarsi, a rostral prong, and most, in addition to the stridulatory comb on the front tibia, have a stridulatory area on the front femur. The secondary stridulatory zone is absent from all Old World Anisopinae. Possible secondary stridulatory features have been described on *Anisops niloti* Poisson from Madagascar (Lansbury, 1966).

Unusual if not unique in the Anisopinae, the female of *Paranisops endymion* bears several secondary sexual characters (extensions to hind margins of eyes, and projections on the lateral margins of the pronotum). They are more fully described in Lansbury (1964). Females of the related species *P. incynatus* do not exhibit this reversal of secondary



Figs 60-63: *Paranisops endymion* (Kirkaldy) male. (60) side view of 7th tergite, (61) *ibid.*, dorsum of 7th tergite; (62) genital capsule, after Lansbury, 1964; (63) operculum.

sexual characters. The data available for *Paranisops* show that *P. endymion* is restricted to south-west Australia, and the distributional gap between *P. endymion* and *Walambianisops* is extremely wide. Lansbury (1964) observations on *P. inconstans* were based on limited numbers of specimens from various localities. There was no data on the relative abundance of the "macropterous" or dark form *P. inconstans inconstans* compared with the leucochroic form *P. inconstans* var *lutea* Hale in a population. During 1979 at Cedar Falls near Brisbane *P. inconstans* was found in relatively large numbers in deep, shaded water under a bridge. The "macropterous" form *P. inconstans inconstans* uncommon; one male and two females in a sample of 34 males and 56 females, remainder being *P. inconstans* var *lutea*. *P. inconstans* is an eastern coastal species recorded from N.S.W. and Queensland.

The two species of *Paranisops* are characterised by the flat operculum (Figs 60, 63), the posteriorly cleft genital capsule, the hairy coxal plates, the carinate frons and the thin plate-like first gonapophysis. *P. endymion* males have symmetrical parameres, females

have secondary sexual characters. The chaetotaxy of the male and female front legs is similar except in the claws which are dimorphic. *P. inconstans* males have asymmetrical parameres, the chaetotaxy of the male front leg differs markedly from that of the female, the claws are not sexually dimorphic, and the female does not have any obvious secondary sexual characters (as exhibited by *P. endymion*). The similarities and quite striking differences between these two species suggests that generic concepts within the Anisopinae are fairly flexible.

Key to Australian genera of Notonectidae

1. Hemelytral commissure continuous, without a hair-lined pit close to the apex of the scutellum (Notonectinae) 2
- Hemelytral commissure with a prominent hair-lined pit close to the apex of the scutellum (Anisopinae) 4
2. Mid-femur with a large spine ante-apically (Fig. 33). Eyes dorsally widely separated (Fig. 26) 3
- Mid-femur with a small spine ante-apically. Eyes dorsally contiguous forming an ocular commissure, i.e. appearing to be

joined or overlapping, no synthipsis

Nychia

3. Antero-lateral margins of the pronotum not foveate

Natonecta

Antero-lateral margins of the pronotum foveate (Figs 26, 32)

Enithares

4. Coxal plates shining, sometimes coarsely striate, distally occasionally fringed with black hairs

5

Coxal plates covered with black hairs

Paramisops

5. Antennae two-segmented (Fig. 43)

Walambianisops gen. nov.

- Antennae three-segmented

Anisops

Alternative key to Australian genera of Anisopinae

1. Prominent rostral prong. Front tibia enlarged apically with a row of stridulatory pegs. Front tarsus one-segmented in male, two-segmented in female. Operculum carinate

Anisops

Rostral prong absent. Front tibia not enlarged apically to accommodate stridulatory pegs (if present). Front tarsi two-segmented in both sexes. Operculum either flat or convex

2

2. Coxal plates bare. Front femur with four groups of setae. Pegs of stridulatory row all clearly separate. Antennae two-segmented. Frons and vertex bulbous

Walambianisops

- Coxal plates covered in black hairs. Front femora without groups of setae. Stridulatory pegs absent. Antennae three-segmented. Frons and vertex carinate

Paramisops

Family: NEPIDAE

Austronepe angusta (Hale)

Crieta angusta Hale, 1924, pp. 508–509

Austronepe angusta: Menke & Stange, 1964, pp. 67–72 (new genus for *angusta*).

Austronepe angusta: Lansbury, 1967, pp. 641–644

Austronepe is widely distributed through the tropical fringe of the Northern Territory and in Queensland down to Stradbroke Island. Breeding sites vary. They include road-side pools and ditches with or without dense growths of macrophytes (as in Queensland near Marceba), small shallow grassy pools (e.g. by the Mary River along the Arnhem Highway, N.T.), and large billabong (e.g. near Nourlangee Rock, Northern Territory, where *Austronepe* was found in deep water amongst *Pondurus* roots). It is fairly common at Fogg Dam near Darwin which has clear water, and abundant at McMinns Lagoon also near Darwin, where the water is extremely turbid. Although found in a wide variety of habitats, all are lentic or slow lotic. Little

variation is apparent in size and external morphology of the species, and the male genitalia are uniform throughout the range.

Material examined: W.A.: WAM 79-149–55. Kalumburu Mission, Kimberley, 1.1960. A. M. Douglas & G. Mees, two males, two females and three immatures (4th–5th instar), in the Western Australian Museum, Perth.

Ranatra diminuta Montandon

Ranatra longipes var. *diminuta* Montandon, 1907, p. 57.

Ranatra diminuta Montandon: Lansbury, 1972, pp. 323–326 (var. *diminuta* elevated to species).

In Lansbury (1972), specimens from north-west Australia of *R. diminuta* key out as *R. longipes* Stål, because the eyes are clearly wider than the interocular space. However, the male genitalia of the two species are distinctive; the parameres of *R. diminuta* have a prominent tooth distally, this projection is missing in *R. longipes*. The status of several species of *Ranatra* from the Australasian region is open to question. A possible synonym of *R. diminuta* is *R. biroi* Lundblad (1933) described from New Guinea (Astrolabe Bay). Comparison of the types of *R. biroi* with those of *R. diminuta* seemed to indicate that the status of both species was valid (Lansbury, 1972). However, more recent studies of additional material from Australia, New Guinea and the Philippines has shown that characters previously used, such as eye width-interocular space, distance between middle coxae compared with hind coxae, and elevation of vertex above eyes—are all taxonomically unreliable. Another species described from Millstream, Western Australia (*R. occidentalis* Lansbury) is also part of the *R. diminuta* complex. As *R. occidentalis* appears to be geographically isolated from mainland Australia *R. diminuta*, it is still tentatively regarded as a distinct species. Typical *R. diminuta* is fairly common in the Philippines, but there is a high level of trivial variation in the shape of the parameres (see Lansbury, 1972). A large series of *R. diminuta* from Queensland has: 49% have the eye width equalling interocular space, 37% have the eye width less than interocular space, 14% have the eye width greater than interocular space. The simplistic shape and lack of "ornamentation" throughout most of the small oriental *Ranatra* renders the species limits obscure.

Material examined: W.A.: WAM 79-126. Wotjulum Mission via Derby, Kimberley.

xi).1955, A. M. Douglas, two males and two females in the Western Australian Museum, Perth.

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PHYSICOCHEMICAL AND BIOLOGICAL STUDIES ON THE COORONG LAGOONS, SOUTH AUSTRALIA, AND THE EFFECT OF SALINITY ON THE DISTRIBUTION OF THE MACROBENTHOS

BY *M. C. GEDDES*

Summary

During 1982 there was no outflow from the barrages at the mouth of the River Murray and the Coorong was a hypermarine system. In the North Lagoon spatial and seasonal patterns of salinity were apparent with salinities highest (to 80‰) at the more southerly stations in the summer months. Salinities were between 90 and 100‰ in the South Lagoon. The macrobenthos in the North Lagoon was dominated by the amphipods *Melita zeylanica*, *Paracorophium* sp. and *Megamphopus* sp., the polychaetes *Ceratonereis pseudoerythraensis*, *Nephtys australiensis*, *Capitella capitata* and *Ficopomatus enigmaticus*, the bivalves *Notospisula trigonella* and *Arthritica semen* and the gastropods *Hydrobia buccinoides* and *Salinator fragilis*. The species number was low, possibly reflecting the extreme salinity fluctuations in the Coorong. High salinity in the southern end of the North Lagoon restricted the distribution of most species. The fauna of the South Lagoon was a salt lake assemblage including dipterans, especially the chironomid *Tanytarsus barbitarsus* and the ephydrid *Ephydrella* sp., the ostracod *Diacypis compacta* and the isopod *Haloniscus searlei*; the only fish present was the hardyhead *Atherinosoma microstoma*. The salinity regime in 1982 represented an extremely hypermarine phase in the long term salinity fluctuations of the Coorong. In periods of sustained high River Murray outflow in the mid 1970s, salinities were estuarine in the North Lagoon and from 30-70‰ in the South Lagoon.

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by M. C. GEDDES & A. J. BUTLER*

Summary

GEDDES M. C. & BUTLER, A. J. (1984) Physicochemical and biological studies on the Coorong Lagoons, South Australia, and the effect of salinity on the distribution of the macrobenthos. *Trans. R. Soc. S. Aust.* **108**(1), 51-62, 12 June, 1984.

During 1982 there was no outflow from the barrages at the mouth of the River Murray and the Coorong was a hypermarine system. In the North Lagoon spatial and seasonal patterns of salinity were apparent with salinities highest (to 80‰) at the more southerly stations in the summer months. Salinities were between 90 and 100‰ in the South Lagoon. The macrobenthos in the North Lagoon was dominated by the amphipods *Melita zeylanica*, *Paracoro-phium* sp. and *Alegamphopus* sp., the polychaetes *Ceratonereis pseudoerythraensis*, *Niphtys australiensis*, *Capitella capitata* and *Eteopomatus cingulatus*, the bivalves *Notaspisula trigonella* and *Arthritica semen*, and the gastropods *Hydrobia buccinoides* and *Salinator fragilis*. The species number was low, possibly reflecting the extreme salinity fluctuations in the Coorong. High salinity in the southern end of the North Lagoon restricted the distribution of most species. The fauna of the South Lagoon was a salt lake assemblage including dipterans, especially the chironomid *Tanytarsus barbitarsus* and the ephydrid *Ephydrella* sp., the ostracod *Diacypris compacta* and the isopod *Haloniscus scurlei*; the only fish present was the hardyhead *Atherinosoma miterostoma*. The salinity regime in 1982 represented an extremely hypermarine phase in the long term salinity fluctuations of the Coorong. In periods of sustained high River Murray outflow in the mid 1970s, salinities were estuarine in the North Lagoon and from 35-70‰ in the South Lagoon.

KEY WORDS: Physicochemistry, Coorong Lagoons, salinity, macrobenthos, hypermarine system.

Introduction

The Coorong is a coastal lagoon system which extends from the mouth of the River Murray some 100 km southeast along the South Australian coast (Fig. 1). It is divided into North and South lagoons by a constricted area which limits water exchange. The North Lagoon has an area of approximately 73 km² and a volume of approximately 73 000 Ml in summer; corresponding values for the South Lagoon are 80 km² and 93 000 Ml. Both lagoons are shallow with mean depths of 1.0 m and 1.1 m for the North and South lagoons respectively. The Coorong was formed when rising sea level flooded an old intertidal corridor about 6,000 years B.P. (von der Borch 1975). A barrier dune, the Younghus-band Peninsula, was built up and seawater access was gradually restricted. Deposits within the Coorong suggest that the system assumed its present lagoonal character perhaps 3,000 years B.P. (Browne 1965)¹. The present Coorong has only a restricted entrance via the narrow channel at the Murray mouth. The

only freshwater inflow is from the River Murray which is at the extreme northern end of the lagoon system. There is at present no significant run-off elsewhere along the lagoons, although historical records indicate that flows may have entered via Salt Creek in the first half of the century (Noye 1975). Under the present regime much of the environment of the Coorong is likely to be hyperhaline (*sensu* Barnes 1980).

Most of the work on the Coorong lagoons has been of a geological (Browne 1965¹; von der Borch 1965, 1975) or hydrological (Noye 1970²; Noye & Walsh 1976) nature, although some consideration of the plants, fish and aquatic birds is given in Noye (1975). The Coorong is acknowledged as a major habitat for aquatic birds and some work has been done to estimate bird numbers and to study the major food chains in the Coorong leading

¹ Browne, R. G. (1965) Sedimentation in the Coorong, South Australia. Ph.D. Thesis, University of Adelaide (unpublished).

² Noye, B. J. (1970) On the physical limnology of shallow lakes and the theory of tide wells. Ph.D. Thesis, University of Adelaide (unpublished).

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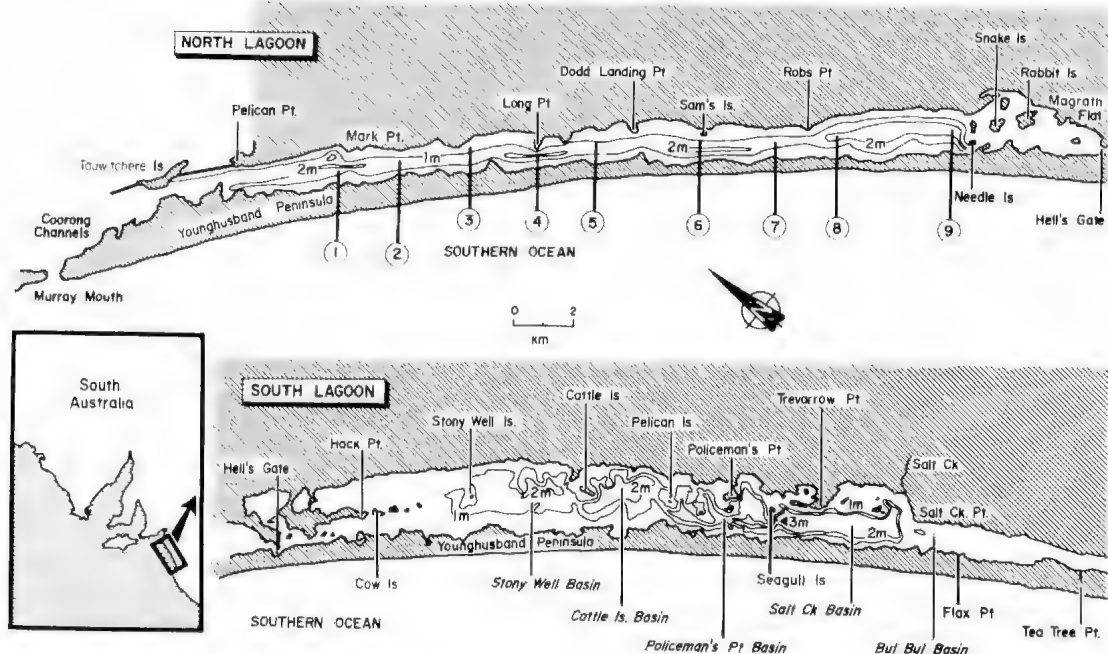


Fig. 1. The Coorong lagoons showing stations (1-9) sampled in this study. Bathymetric contours are based on Noye (1975) and are approximate.

to aquatic birds (Delroy *et al.* 1965³; Paton 1982⁴). The Coorong also supports a major fishery and over the six years to 1981-82 the annual catch of yellow-eye mullet (*Aldrichetta forsteri*) has been 105-235 tonnes, that for mulloway (*Sciaena antarctica*) 24-115 tonnes and for black bream (*Acanthopagrus butcheri*) from 10-72 tonnes⁵. Some studies have been made on the biology of the yellow eye mullet (Harris 1968) and the black bream (Weng 1970⁶).

The present study constitutes a limnological survey of the Coorong during 1982, with particular emphasis on the effect of salinity on the distribution of macroinvertebrates. In addition some analysis is made of the longer term

salinity variations in the Coorong and their likely biological consequences. Comparisons are made with studies on other Australian coastal lagoon systems, including the Peel-Harvey system in Western Australia (Hodgkin *et al.* 1980⁷), the Gippsland Lakes in Victoria (Poore 1982) and Lake Macquarie (MacIntyre 1959) and the Tuggerah Lakes (Powis & Robinson 1980; Collett *et al.* 1981), New South Wales. The Peel-Harvey system is most similar to the Coorong as it also has a hyperhaline zone.

Methods

Physico-chemical

Monthly visits were made to the North Lagoon from December 1981-March 1983, and samples were taken from 9 stations (Fig. 1). Samples were collected from the South Lagoon in April (7 sites) and November (10 sites) 1982. At each site conductivity (K_{25}) and temperature profiles were measured with a Martek Mark V Water Quality Meter. Light penetration was estimated with a Secchi disc. Surface and bottom (10 cm above sediments) water samples were taken from stations 1, 3, 5, 7 and 9 in the North Lagoon and from the sites sampled in the South Lagoon. In the laboratory the conductivity (Radiometer CDM

³ Delroy, L. B., Macrow, P. M. & Sorrell, J. B. (1965) The food of waterfowl (Anadidae) in salt water habitats of South Australia. Unpublished report of Fisheries and Fauna Conservation Department of South Australia.

⁴ Paton, P. (1982) Biota of the Coorong, South Australia Department of Environment and Planning, Nov. 1982. S.A.D.E.P. 55 (unpublished).

⁵ SAFIC February 1982, April 1983 (unpublished).

⁶ Weng, H. T. C. (1970) The black bream *Acanthopagrus butcheri* (Munro): its life history and its fishery in South Australia. M.Sc. Thesis, Zoology Department, University of Adelaide (unpublished).

2e meter) and turbidity (Hach 2100A Turbidimeter) were measured, chlorophyll *a* concentration was calculated by the SCOR UNESCO trichromatic method (Anon 1976) and total P determined by digestion with perchloric acid and measurement via the Stannous Chloride Method (Anon 1976). In addition to the samples collected in 1981–83, conductivity measurements were made on some earlier collections.

Conductivity values were generally hypermarine and so practical salinity could not be calculated from the International Oceanographic Tables (UNESCO 1981). As an estimate of salinity, conductivities were converted to values for total dissolved solids (TDS) using the regression equation of Williams (1966). This equation was developed for Australian saline lakes but comparison of measured TDS (dry weight of residue after drying at 102°C) for 30 samples from the Coorong over the K_{25} range 18 to 130 mS cm⁻¹ with calculated TDS values showed close agreement (Fig. 2). This is to be expected considering the similar nature of ionic dominance in Coorong water and Australian salt lakes (Williams & Buckney 1976).

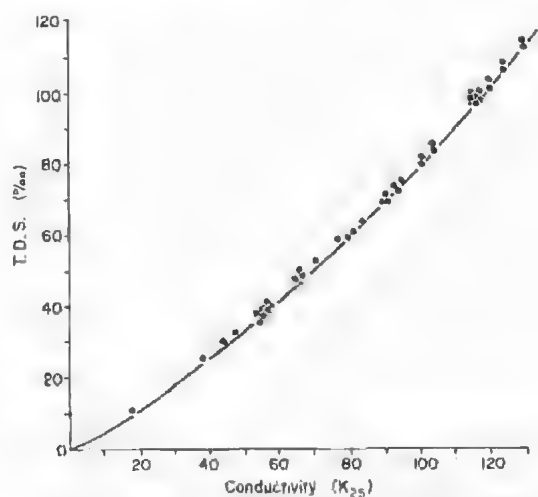


Fig. 2. Relationship between conductivity (K_{25}) and TDS (%ss). The line represents the regression equation of Williams (1966). The points are values of K_{25} and TDS by weight for samples from the Coorong lagoons.

Biological

Biological samples were taken from stations 1, 3, 5, 7 and 9 in the North Lagoon each month, and from the sites in the South Lagoon. Macroinvertebrates were collected

in three ways. Ekman Birge grab samples were taken from the mud in mid-lagoon (1.5–2.5 m depth) while in the littoral region a handnet was used among the macrophyte beds and an epibenthic trawl was pulled through the shallows (both nets with mesh size 0.5 mm). On return to the laboratory, collections were washed through a 0.5 mm sieve and animals picked out and preserved. Later each sample was inspected under a stereodissecting microscope, specimens identified and the relative abundance of species noted. Animals on hard substrates were collected occasionally but cryptic or small organisms on or under rocks were not collected. No samples were taken from sand substrates on the Younghusband Peninsula shore of the lagoons.

Samples of aquatic macrophytes were taken for identification and on some occasions filamentous algae were collected. Water samples were examined to determine which algae were the dominant phytoplankters.

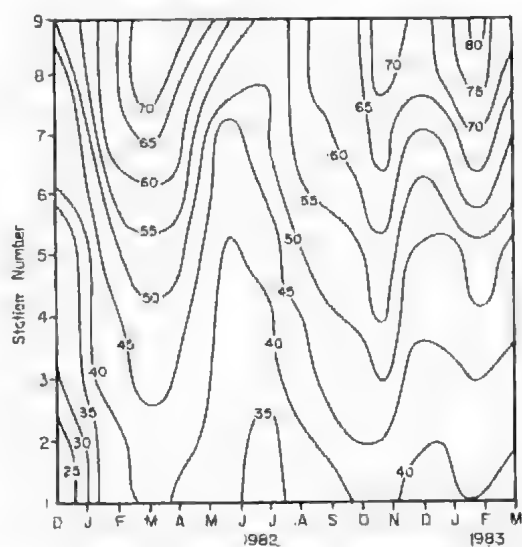


Fig. 3. Surface salinity (TDS %ss) at 9 stations in the Coorong, North Lagoon, over 15 months.

Results

North Lagoon

Surface salinity at the 9 stations over the 15 month period is shown in Fig. 3. In December 1981 salinities at stations 1–5 were below that of sea water, but all other salinities were hypermarine. A gradient persisted with salinities always lowest at station 1, closest to the Murray mouth, and highest at station 9;

salinities along the lagoon ranged 20–50‰ in December 1981 and 40–80‰ in January 1983. A seasonal pattern was apparent with salinities high in summer 1981–82, falling during May, June and July and rising again in October to a peak value in January 1983. However the changes in salinity were not purely gradual seasonal ones; the abrupt rise in salinities in October was followed by a fall in November before a rise again in December and a rather abrupt fall in February–March 1983. There were also some occasions when a vertical salinity gradient existed with salinities at the bottom up to 5‰ above those at the surface. These variations probably reflect wind-induced currents, with either seawater entering from the Murray mouth flowing southwards over saltier water, or highly saline water coming northwards along the bottom from the South Lagoon.

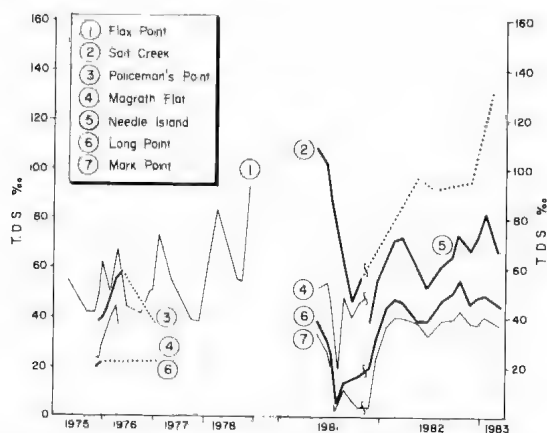


Fig. 4. Surface salinities (TDS ‰) measured at various sites in the Coorong lagoons. Broken lines are used where samples were taken at long time intervals apart. Note the break and change of scale of the X axis. The values for Salt Creek, Magrath Flat, Long Point and Mark Point from May–October 1981 are calculated from field conductivity measurements made by the Engineering and Water Supply Department.

Some information on longer term fluctuations in salinity is presented in Fig. 4, indicating that salinities during 1982 were particularly high. In the mid 1970's the North Lagoon was estuarine and from 1975–1977 the southern end of the South Lagoon (Flax Pt) showed fluctuations from around 40‰–70‰. In early 1981 salinities were high in both lagoons but they fell to low values, particularly in the North Lagoon, prior to the commencement of the present sampling program.

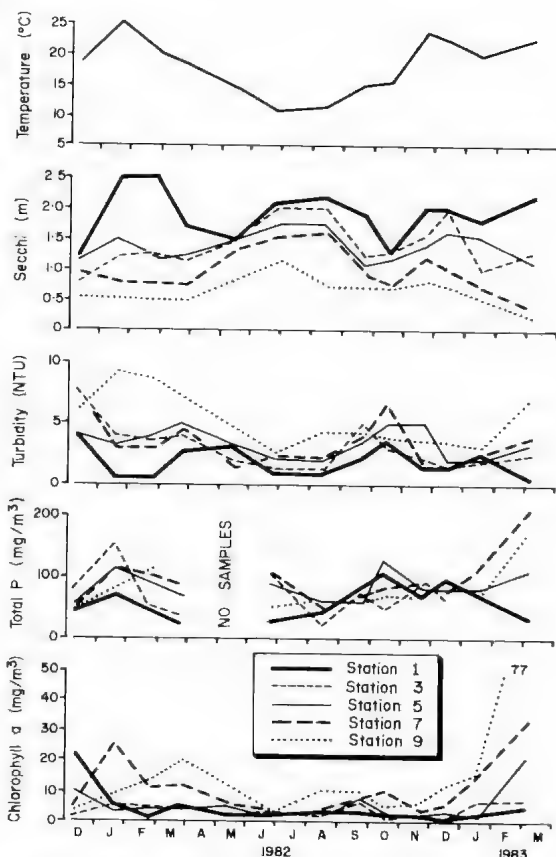


Fig. 5. Physicochemical measurements at 5 stations in the Coorong, North Lagoon over a 15 month period. Surface temperature did not differ significantly between stations.

Water temperatures varied 11–25°C and there was never more than 0.5°C difference between surface and bottom temperature (Fig. 5). Water was always clearest, as indicated by high secchi transparency and low turbidity, at station 1 and clarity decreased southwards (Fig. 5). There was no apparent seasonal pattern to water clarity and it is likely that variations reflect local weather conditions. Total P showed no apparent pattern seasonally or along the lagoon (Fig. 5). The mean value was 79 mg m⁻³.

Chlorophyll *a* values were generally below 10 mg m⁻³ (Fig. 5), highest values were at the southerly stations (7 and 9). At most times diatoms were the dominant algal group in the phytoplankton. In January, February and March 1982 and 1983 blooms of flagellates occurred at station 5, 7 and 9 and chlorophyll *a* rose to high levels.

Although no systematic collections were taken of macrophytes or filamentous algae, some comments can be made on their distribution and abundance. The macrophyte beds occurred on the shallow landward shelf where water depth was less than 1 m; occasionally patches occurred in deeper (to 2 m) water mid-lagoon. *Ruppia megacarpa* was the dominant macrophyte, occurring at all sites throughout the study. *Lepilaena cylindrocarpa* was common from stations 3–7. *Zostera muelleri* was common from stations 1–5 and a few plants were collected from station 7. From October to February mats of filamentous algae, including *Cladophora*, *Enteromorpha* and *Oscillatoria*, occurred among the macrophyte beds and covered much of the bottom of the lagoon.

The macroinvertebrates collected in the North Lagoon are listed in Table 1. At stations 1, 3 and 5 there were no seasonal patterns of

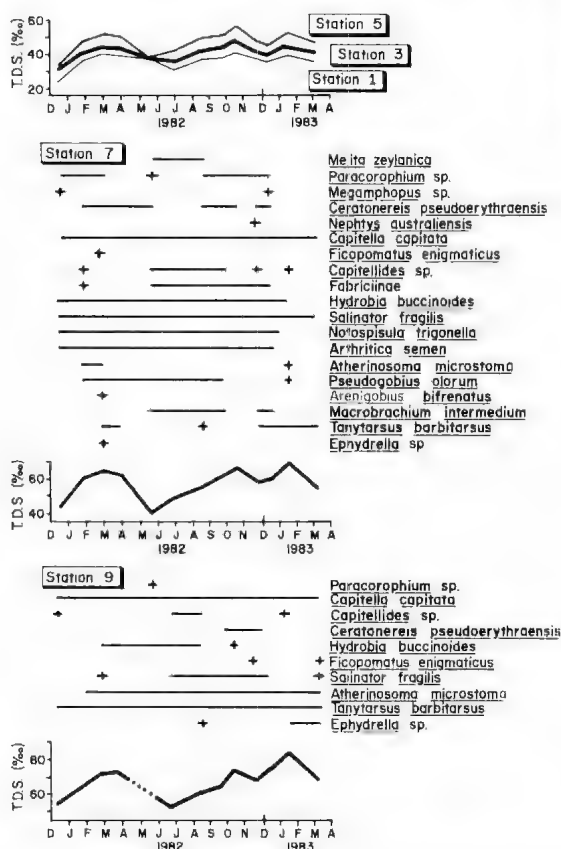


Fig. 6. Salinities (TDS ‰) at 5 stations in the Coorong, North lagoon, over 15 months (simplified from Fig. 3), and presence of animal species at the two most saline stations, 7 and 9.

occurrence with most species collected on most occasions. Mean summer salinities (October 1982–March 1983) at these stations were 38.8, 44.0 and 50.6‰ with peak values of 42.6, 50.5 and 57.6‰ (Fig. 6). At stations 7 and 9 mean summer salinities were 61.5 and 72.3‰ with peak values 68.5 and 81.6‰. Although many species were collected during the winter months, especially from station 7, as salinities rose most species became rarer and only *Capitella capitata*, *Salinator fragilis*, *Atherinosoma microstoma* and the dipteran larvae were common in the summer of 1982–83.

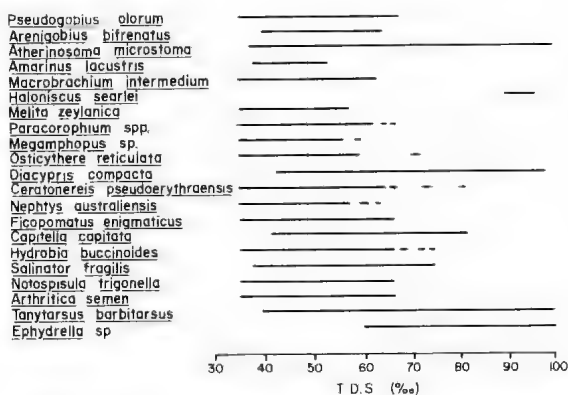


Fig. 7. Distribution of animal species in the Coorong lagoons related to salinity (TDS ‰). Broken lines indicate isolated collections of only one or a few specimens.

The distribution of the fauna with respect to salinity is shown in Fig. 7. All species were collected up to 50‰ but above 55‰ many species were absent. At above 65‰ several species were represented by only a few individuals; only five species were collected above 70‰.

The distribution and abundance of each of the groups of animals collected will now be considered more closely.

Fish

Fish were collected in the trawl and the handnet in the littoral regions. Many fry were collected but not identified. The small adult fish comprised three species. The blue spot goby (*Pseudogobius olorum*) was most common from stations 1–7 over the salinity range up to 68‰. The bridled goby (*Arenigobius bifrenatus*) was collected less frequently, but over a similar salinity range (to 65‰). Both gobies occur in estuaries and

TABLE 1. *Macroinvertebrates and fish collected from the North Lagoon of the Coorong during 1982.*

Fish	<i>Arenogobius bifrenatus</i> (Kner)
	<i>Pseudogobius olorum</i> (Sauvage)
	<i>Atherinosoma microstoma</i> (Günther)
Crustaceans	Decapods <i>Amarinus lacustris</i> (Chilton)
	<i>Macrobrachium intermedium</i> (Stimpson)
	Amphipods <i>Melita zeylanica</i> Stebbing
	<i>Paracorophium</i> spp.
	<i>Megamphopus</i> sp.
	Ostracods <i>Osticythere reticulata</i> Hartmann
	<i>Diacypris compacta</i> (Herbst)
Polychaetes	<i>Ceratonereis pseudoerythraensis</i> Hutchings
	<i>Nephtys australiensis</i> (Fauchald)
	<i>Australonereis ehlersi</i> (Augener)
	<i>Ficopomatus enigmaticus</i> (Fauvel)
	<i>Boccardia chilensis</i> Blake and Woodwick
	<i>Capitella capitata</i> (Fabricius)
	<i>Capitellides</i> sp.
	Fabriciinae
Gastropods	<i>Hydrobia buccinoides</i> (Quoy and Gaimard)
	<i>Salinator fragilis</i> (Lamarck)
Bivalves	<i>Notospisula trigonella</i> (Lamarck)
	<i>Arthritica semen</i> (Menke)
	<i>Tellina mariae</i> (Tenison-Woods)
	<i>Soletellina donacioides</i> Reeve
Insects	Chironomid <i>Tanytarsus barbitarsus</i> Freeman
	Ephydrid <i>Ephydrella</i> sp.

coastal lakes from Queensland to Western Australia (Hoesé & Larson, 1980). The small mouthed hardyhead (*Atherinosoma microstoma*) was collected from all stations and was particularly common at 7 and 9. This species also occurred in the South Lagoon at salinities up to 100‰. *A. microstoma* is common in shallow lagoons and brackish water lakes from the Tuggerah Lakes in N.S.W. to the Coorong (Ivanstoft 1980).

Crustaceans

The small spider crab *Amarinus lacustris* was collected on two occasions from station 3 and once from station 5 at salinities of 38.2, 43.3 and 53.2‰. This crab is normally restricted to fresh or slightly brackish water with other species of Hymenosomatidae usually found in estuarine and marine situations (Walker 1969; Lucas 1980). The shrimp *Macrobrachium intermedium* was collected in handnet samples from among macrophyte beds on ten occasions from stations 3, 5 and 7 in salinities ranging up to 63‰. The species is common in weedbeds in the S.A. gulfs (Hale 1927) and in estuaries in south-eastern and southwestern Australia (Poore 1982; Hodkin pers. comm.).

Amphipods were very abundant on the plants and mud in the littoral regions. Three species occurred in high abundance, *Melita*

zeylanica, *Paracorophium* sp. 1 and *Megamphopus* sp. at stations 1–5. A few specimens were collected from station 7 during winter and spring but none were collected in January or March 1983. The distribution and salinity tolerance of the amphipods is discussed in Kangas & Geddes (in press).

The ostracod *Osticythere reticulata* was common in many collections at salinities up to 60‰ and a few specimens were collected at 72.4‰. This is an estuarine species described from the Hopkins River and the Gippsland Lakes, Vic. (Hartmann 1980). *Diacypris compacta*, a salt lake ostracod recorded from ephemeral salt lakes along the Coorong (De Deckker & Geddes 1980), was collected on a few occasions.

Polychaetes

Of the several species of polychaetes listed in Table 1 only four were common. *Ceratonereis pseudoerythraensis* was abundant in all benthic samples from stations 1, 3 and 5 and *Nephtys australiensis* in benthic mud samples from those stations. The former is known from estuaries and embayments from S.A., W.A. and N.S.W. (Hutchings & Turvey 1982) while the latter is found in sand and mud substrates in bays, lagoons and estuaries from southern Qld to Spencer Gulf (Rainer & Hutchings 1977; Hutchings 1982). Most

records of *C. pseudoerythraensis* and *N. australiensis* were from below 65 and 57‰ respectively, although some specimens of the former species were collected at salinities as high as 72‰ and some of the latter species at 64‰. *Capitella capitata* was collected occasionally from stations 3 and 5 but was most abundant at stations 7 and 9 at salinities up to 82‰; it was the only polychaete at stations 7 and 9 in the summer of 1982–83. It is recorded from W.A. along southern shores to N.S.W. in muddy sediments in estuarine and shallow protected areas (Hutchings 1982). The cosmopolitan brackish water serpulid *Ficopomatus enigmaticus* was common in the littoral areas of stations 1, 3 and 5 and large mounds of live tube worms occurred. Mounds of empty tubes were common at stations 7 and 9. The highest salinity at which large populations of active worms were seen was 67‰ but some newly settled solitary individuals were found at higher salinities.

Molluscs

Of the gastropods, *Hydrobia buccinoides* was extremely abundant in the littoral macrophyte beds at stations 1, 3 and 5 throughout the study, at station 7 until December 1982, and at station 9 during the middle of 1982. The highest salinity at which large populations occurred was 66‰ although a few individuals were collected up to 74‰. *Salinator fragilis* was present in lower numbers but it persisted at station 7 throughout the study and was often collected from station 9 at salinities up to 74‰. Species of *Hydrobia* are characteristic of estuarine and lagoonal environments in Europe (Barnes 1980, p. 59) and *H. buccinoides* was common in the Tuggerah Lakes (Collett *et al.* 1981). *Salinator fragilis* is common in estuaries and sheltered embayments in southeastern Australia (Poore 1982; Collett *et al.* 1981; Butler *et al.* 1977).

The most common bivalve was *Notosipula trigonella* which was collected from stations 1, 3 and 5 throughout the study and station 7 until December 1982; highest salinity for the species was 66‰. At station 9 there were extensive deposits of empty shells. The small bivalve *Arthritica semen* generally was collected along with *Notosipula*. The other species of bivalves were collected only occasionally. *Notosipula trigonella* is recognized as a widespread estuarine species in south-eastern Australian estuaries (Poore 1982) and

it and *Arthritica semen* are among the dominant bivalves in the Peel–Harvey system (Hodgkin *et al.* 1980)⁷.

Dipterans

The chironomid *Tanytarsus barbitarsus* occurred occasionally all along the lagoon but very large numbers were collected at stations 7 and 9 from October 1982 to March 1983 when they were easily the most numerous invertebrate. At stations 7 and, especially, 9 *Ephydiella* sp. and a few specimens of Ceratopogonidae were collected. These dipterans are characteristic of inland saline lakes (Williams 1981).

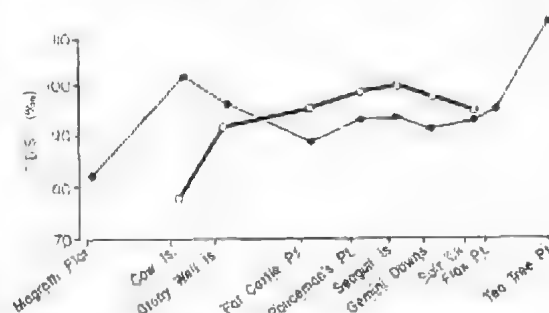


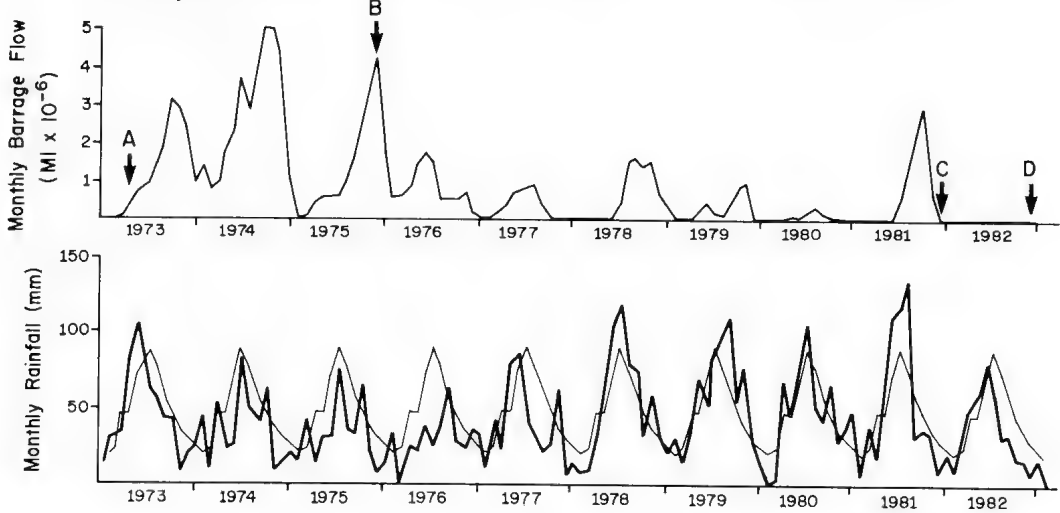
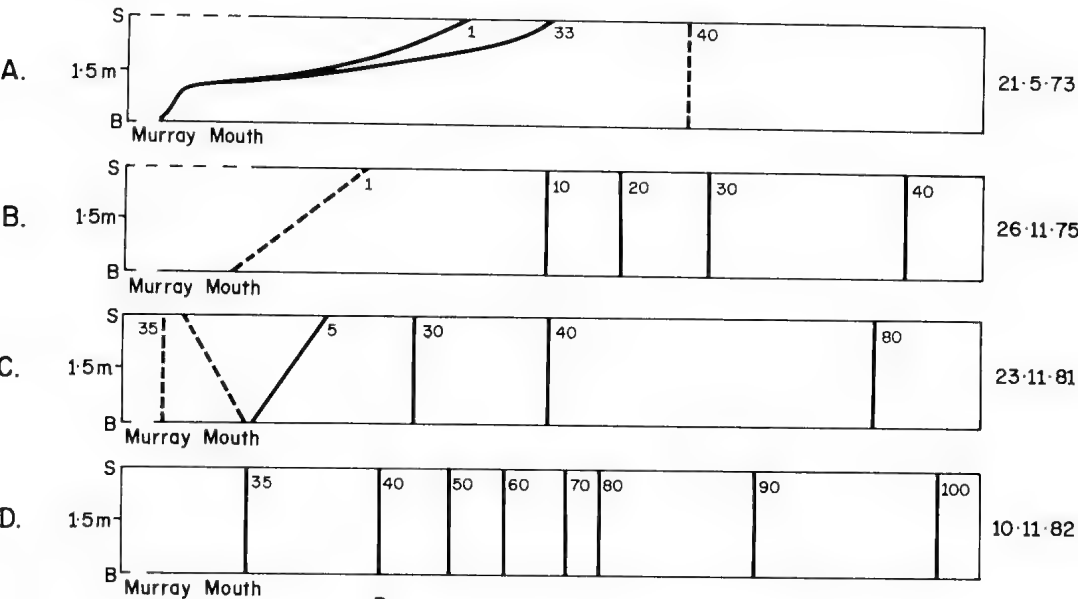
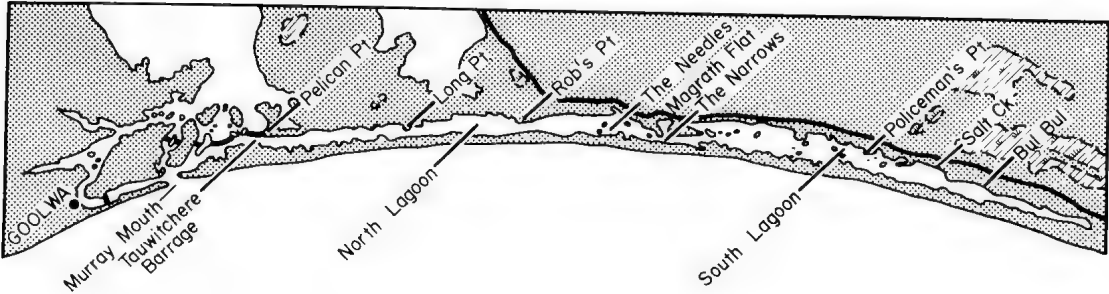
Fig. 8. Salinities (TDS ‰) measured on two occasions at various sites in the Coorong, South lagoon. Open circles: 16 and 17, April 1982. Closed circles: 9 and 10, November 1982.

South Lagoon

The South Lagoon was sampled on two occasions and the salinities are shown in Fig. 8. On both occasions the salinity was rather similar from Stony Well Island southwards 24 km to Salt Creek, at values around 97‰ in April and 93‰ in November. This indicates that the lagoon was well-mixed and/or that it had little exchange with the North Lagoon and received no significant inputs of fresh water.

Mean total phosphate was 110.5 mg m⁻³ (SD 15) in April and 87.3 mg m⁻³ (SD 23.6) in November. Mean secchi depths were 45 cm and 30 cm and mean chlorophyll *a* values 21.6 mg m⁻³ (6.3) and 29.2 mg m⁻³ (5.0). There were no clear trends in any of these parameters along the lagoon on either sampling date.

⁷ Hodgkin, E. P., Birch, P. B., Black, R. E., Humphries, R. B. (1980) The Peel–Harvey Estuarine System Study (1976–1980) Report No. 9, Department of Conservation and Environment, Western Australia, 72 pp. (unpublished).



No live *Ruppia* was collected on either trip although small quantities of dead *Ruppia* leaves, presumably *R. tuberosa*, were collected in the littoral samples. The only fish collected from the South Lagoon was *Atherinosoma microstoma*; it occurred in very large numbers and was collected at most stations. The crustaceans comprised the isopod *Halinivens scutell* and the ostracod *Diccypris compacta*; a few specimens of *Cypridus australiensis* and *Reticypris* sp. were also collected. Dipterans were the most numerous animals and included ceratopogonids, tabanids, stratiomyids and especially the chironomid *Tanytarsus barbatus* and the ephydriid *Ephydrella* sp. On mud flat areas, particularly south of Salt Creek, the gastropod *Coxiella* sp. and the beetles *Clavina* sp. (Carabidae) and *Bledius* sp. (Staphylinidae) were abundant.

Discussion

The Coorong lagoons are characterized by the variety and degree of their salinity fluctuations. Salinity varies along the length of the Coorong. On occasions there are vertical salinity gradients, and there are seasonal and long-term patterns. A range of salinity patterns is represented in Fig. 9 which shows horizontal and vertical gradients in salinity at different occasions since 1973. On each occasion there is a gradient towards hypermarine salinities in the South Lagoon. This suggests that the dominant freshwater influence on the Coorong is from the River Murray barrages. Salinity values in the South Lagoon vary widely from 40‰ to more than 100‰. When the barrages are open or only recently closed (Fig. 9A,B,C), a vertical salinity profile exists at the northern end of the North Lagoon.

The salinity patterns can be interpreted with respect to outflow from the River Murray barrages and to rainfall in the southern region of the Coorong (Fig. 9). The high River Murray flows in 1973-75 resulted in the

barrages being open almost continuously providing fresh water at the Murray Mouth. The fresh water was available for mixing to the south, maintaining estuarine conditions over most of the Coorong in 1975 (Fig. 9B). These low salinities occurred even though rainfall in the southern area of the Coorong was below average in 1974 and 1975. For most months in 1980 and the first part of 1981 the barrages were closed, salinities at the mouth would have been at about that of sea water and southward the Coorong would have become progressively more hypermarine. The brief period of high flow from the Murray in July to October 1981 provided some dilution of the North Lagoon, but seems to have had little effect on the South Lagoon (Fig. 9C). The barrages were then closed for the 12 months up to November 1982, sea water would have re-entered the mouth area, and salinities along the lagoons became progressively more hypermarine (Fig. 9D). The above-average rainfall in the southern Coorong area in 1981 did not reduce salinities significantly. The important role of freshwater from the River Murray in controlling salinities in the Coorong is also apparent in earlier periods. The high salinities in the late 1960's and early 1970's which prompted much environmental concern (Noye 1975), followed low flows from the River Murray and long periods of barrage closure from 1965 to 1969.

Although there is a relationship between River Murray flow and salinity in the Coorong lagoons, it may be that the period of time for which freshwater is available at the Murray mouth is more important than the flow *per se*. Flows were high in mid-1981, providing an above-average flow for the year 1981-82, but the barrages were open for only a few months and the availability of fresh water for this short period did not bring about a general fall in salinities in the southern parts of the Coorong. When there is fresh water at the

Fig. 9. Horizontal and vertical patterns of salinity along the Coorong lagoons at four different periods and the relationship between Coorong salinity and River Murray outflow via the barrages and rainfall in the southern Coorong region. The four salinity profiles are taken from the Murray mouth to Bul Bul Lagoon and correspond to the map on the top of the Figure. Broken lines are possible values. Barrage outflow values are estimated by the Engineering and Water Supply Department. Arrows on the flow diagram show times when salinity profiles were taken.

- Following opening of the barrages fresh water overlies saline water in the North Lagoon.
- After two years of good flow from the barrages the North Lagoon is estuarine and the South Lagoon is at about seawater salinities.
- Following closing of the barrages, sea water intrudes through the mouth; most of the North Lagoon is estuarine.
- After a long period of barrage closure the Coorong becomes a hypermarine system with salinities up to three times seawater in the South Lagoon.

Murray mouth it can be moved southeast and mixed by wind action (Noye & Walsh 1976), thus gradually reducing salinity in more southerly areas of the Coorong. Lengthy periods of continuous outflow from the Murray may be necessary to significantly reduce salinity in the South Lagoon. The complex relationship between River Murray flow and salinity in the Coorong needs further investigation.

The extensive beds of macrophytes, generally dominated by *Ruppia*, are important in the ecology of the Coorong. The macrophytes are covered with epiphytic growth which probably is grazed by many of the invertebrates and they provide shelter for the invertebrates and the small fish. In the North Lagoon *Ruppia megacarpa* was abundant from station 3 southwards. This species is common in estuaries and lagoons in southeastern and southwestern Australian (Brock 1982a). The plants continued to grow in the North Lagoon while salinities were above 60‰ and as high as 80‰. These values are above the salinity range of 12–50‰ found by Brock (1979)⁸. A second species, *R. tuberosa*, has been recorded from the South Lagoon. This is an annual species found in shallow and ephemeral saline water in S.A., W.A. and Vic. (Brock 1982a). It regenerates from sexual perennating organs, the turions, and it also produces large amounts of seed (Brock 1982b). This species appears to be particularly important to the bird life in the Coorong as ducks and swans graze the plants, especially the starch rich turions (Delroy *et al.* 1965)³, and the seeds and turions form a major food source for many of the waders (Paton 1982)⁴. *R. tuberosa* occurred in many salt lakes in the southern Coorong area and at Flax Point in the South Lagoon from 1975 to 1978 (Brock 1979)⁸. The salinity range was 13–230‰; however there is little information on the range of salinities at which germination or regeneration occurs. No growing *R. tuberosa* was collected on either of the trips to the South Lagoon in 1982, and it appears that because of the high salinities this very important plant was rare or absent.

The fauna of the North Lagoon was similar to that recorded in other coastal lagoon systems including the Tuggerah Lakes, N.S.W.,

the Gippsland Lakes, Vic., and the Peel-Harvey system, W.A. The dominant macro-invertebrates in the Coorong were *Notospisula trigonella*, *Hydrobia buccinoides*, *Melita zeylanica*, *Paracorphium* spp., *Megamphopus* sp., *Ceratonereis pseudoerythraensis*, *Nephtys australiensis* and *Macrobrachium intermedium* and all are recorded in one or more of these other lagoons. The amphipods seem to be particularly important in all of these coastal lagoon systems. *Ficopomatus enigmaticus* was abundant in the Coorong but not collected in the other studies, possibly because collecting concentrated only on the infauna. Only 21 species were collected in the Coorong compared to numbers in excess of 100 in many large estuaries in southeastern Australia (Saenger *et al.* 1980; Rainer & Fitzhardinge 1981). In the Gippsland Lakes 90 species were recorded (Poore 1982). Although collecting effort was probably lower in the present study, the fauna does seem to be considerably restricted and many species common in estuaries were absent. This low diversity may reflect the extreme fluctuations in salinity in the Coorong. Species number is also low in the Peel-Harvey System, and especially in the Harvey estuary section where salinities vary most widely (Hodgkin *et al.* 1980)⁷. The species assemblage in the Harvey estuary is similar to that of the Coorong, including *Arthritica semen*, *Notospisula trigonella*, *Salinator fragilis*, *Capitella* sp., *Ceratonereis pseudoerythraensis*, *Melita* sp., *Paracorphium* sp. and chironomids (E.P. Hodgkin pers. comm.).

The species in the Coorong perhaps represent that group from within the broader estuarine fauna that is most euryhaline. All of the species showed especially wide salinity tolerance and all persisted throughout the year thus displaying wide temperature tolerance as well. Our data suggest that for *Amarinus lacustris*, *Melita zeylanica*, *Paracorphium* sp., *Megamphopus* sp., *Osticythere reticulata*, *Hydrobia buccinoides*, *Notospisula trigonella*, *Arthritica semen* and *Ruppia megacarpa*, the salinities tolerated by the populations in the Coorong may be higher than those recorded elsewhere. Although all species recorded were present at salinities up to 55‰, in the hypermarine conditions in the Coorong in 1982 increasing salinity along the lagoons did restrict the distribution of the fauna. When salinities in the North Lagoon reached levels

⁸ Brock, M. A. (1979) The Ecology of Salt Lake Hydrophytes. Ph.D. Thesis, University of Adelaide (unpublished).

above 70‰ the character of the fauna changed, with the estuarine assemblage replaced by one dominated by halophilic dipterans and salt-lake crustaceans.

The salinity regime in 1982 represents an extremely hypermarine phase in the long-term salinity fluctuations of the Coorong lagoons, and this is reflected in the restricted distribution of the fauna. Most members of the fauna have good dispersal powers and at times of lower salinity their distribution would presumably be expanded. In the South Lagoon earlier occurrence of an estuarine-lagoonal fauna was evidenced by mounds of tubes of *Ficopomatus enigmaticus* and shells of *Notospisula trigonella*. Further study is needed to elucidate the conditions under which recolonization of the South Lagoon might proceed.

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SEDIMENTOLOGY AND ORIGIN OF LATE PALAEOZOIC GLACIGENE DEPOSITS AT CAPE JERVIS, SOUTH AUSTRALIA

BY N. F. ALLEY & R. P. BOURMAN

Summary

The most extensive exposure of the Permian glacigene Cape Jervis beds was investigated in the type area, Cape Jervis. The beds are divisible into five units which are interpreted, from the base upwards, as fluvioglacial and glaciolacustrine sediments, lodgement till, fluviolacustrine deposits, a flow till complex and a glaciomarine unit. The basal beds are considered to be the proglacial deposits of an ice-mass advancing northwards along the present Backstairs Passage trough. At its maximum extent the ice over-ran Cape Jervis and plastered lodgement till over a partly frost-shattered bedrock surface. Deglaciation was marked by the development of a kame terrace on which fluviolacustrine sediments and a flow till complex were deposited. Glaciomarine silts and clays were laid down during a late deglacial marine transgression into an isostatically depressed coastal lowland.

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transgression into an isostatically depressed coastal lowland.

KEY WORDS: Cape Jervis, Late Palaeozoic glaciation, lithostratigraphic units, lodgement
till, flow till, fluviolacustrine sediments, glaciomarine deposits.

Introduction

The results presented in this paper form part
of a larger investigation of Late Palaeozoic
glaci-
gene deposits in southern South Aus-
tralia. The paper reports on the results of a
re-examination of the type area of the Cape
Jervis Beds at Cape Jervis (Ludbrook 1967)
and a sedimentary model is proposed to
account for the facies observed.

We have retained the original designation of
"Cape Jervis Beds" from the holotype
section (Ludbrook 1967) rather than assign-
ing them "Formation" status. The latter may
be considered when the extent of the beds is
better known following an examination of
other facies exposed at parastratotype sections
or intersections in boreholes.

Previous Investigations

The Cape Jervis Beds in the type area
extend north and east of the Cape Jervis
lighthouse (Fig. 1; see Fig. 10 for general
location), occupying N-S trending bedrock
depressions. At the coast the beds form part
of a cliff that has been extensively eroded
(Fig. 2), thus leading to the concentrations

of large erratics both in the more recent
alluvial cover and in the near shore zone.

Exposure of the Late Palaeozoic glaci-
gene sediments at Cape Jervis has long been known,
but so far studies of them have failed to recog-
nise the complexity of the sediments and the
association of their characteristics with distinc-
tive glacial depositional environments.

The significance of these beds was first
established late last century (David & Howchin
1897). A report on the Cape Jervis area
(Glacial Research Committee 1898) con-
sidered the glaci-
gene sediments there to
represent the most extensive occurrence of a
genuine till "yet discovered in South Aus-
tralia". The till was described as an unstratified
deposit, varying in colour from grey to almost
black, and full of boulders of all sizes. It was
estimated to exceed 30 m in thickness and was
capped by "variegated (?Miocene) clays", now
known to be glacio-marine sediments (Lud-
brook 1967). The committee invoked the
influence of shore-ice to explain some of the
characteristics of the deposits, particularly the
number of waterworn but striated pebbles
found in the drift.

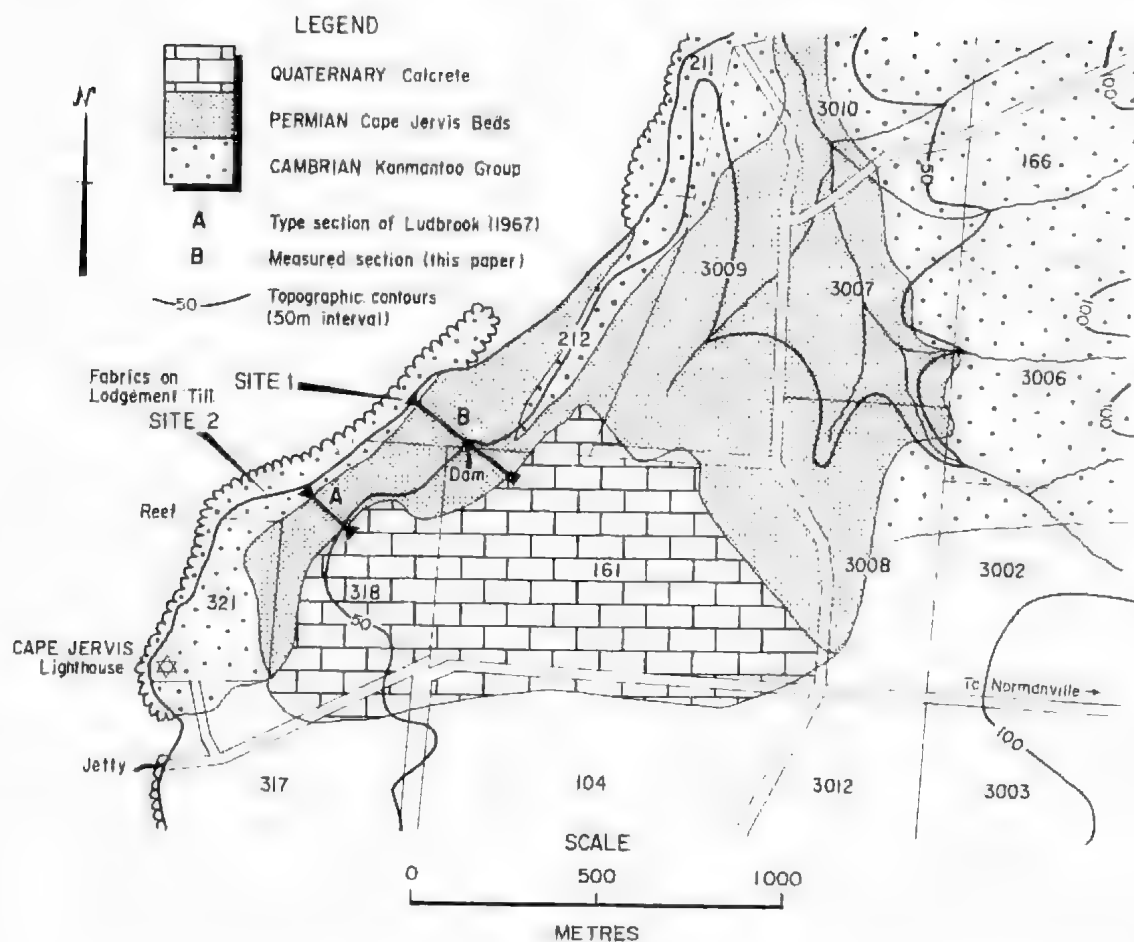
Based on these observations and other evi-
dence Benson (1911) proposed a glacial
origin for Backstairs Passage, a proposal sup-
ported by many subsequent workers (Madigan
1925; Campana & Wilson 1955; Bauer 1959);

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† Bauer, F. H. (1959) Regional geography of
Kangaroo Island. Ph.D. thesis, A.N.U. (unpubl.).



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Fig. 1. Geological sketch of Cape Jervis area (modified from Ludbrook 1980) showing position of type section and new measured section.

Bourman 1973²; Daily *et al.* 1979). During the course of regional geological investigations on Fleurieu Peninsula Campana *et al.* (1953) noted the exposure at Cape Jervis and described the beds as moraines³ consisting "mainly of unsorted, unstratified boulder clay and sandy clay, containing erratics of all sizes and degree of angularity" (p. 5). They also interpreted the rhythmically bedded materials containing dropstones as varves. However, from these local and more extensive studies on Fleurieu Peninsula they did not establish any

clear lithostratigraphic succession in the beds apart from recognising the abundance of boulders and pebbles near their base and sands in their upper sections.

Deposits of till some 20 m thick with interbedded thinly laminated silt and clay beds were described at Cape Jervis by Brock (1964⁴). However, in his map and figure descriptions, bedded sediments were labelled as tills (Brock 1964⁴, fig. 6 and plate 12).

The most definitive work is that of Ludbrook (1967) who established the site as the holostratotype section of the Permian Cape

² Bourman, R. P. (1973). Geomorphic evolution of southeastern Fleurieu Peninsula. M.A. thesis, Univ. Adel. (unpubl.).

³ The term "moraine" is normally restricted to topographic forms rather than to deposits.

⁴ Brock, E. J. (1964) Denudation chronology of Fleurieu Peninsula. M.A. thesis, Univ. Adel. (unpubl.).



Fig. 2. Coastal slope at type area. Steeply dipping Kanmantoo Group metasediments form shore platform and steep cliffs in distance. Positions of features shown by symbols are: G, gully of measured section; D, earthen dam; E, line of large erratics paralleling flow till complex unit. View looking northeast.

Jervis Beds of the St Vincent basin and adjoining areas. From the base, the section is described as: (1) bouldery, sandy till (6.7 m in thickness) unconformably overlying Cambrian Kanmantoo Group bedrock; (2) dark grey boulder till (1.5 m); (3) gritty sandstone with boulders and interstratified clay (3.9 m); (4) crossbedded sandstone (1.5 m); (5) clay shales with grits and boulders (9.0 m); (6) and obscured sediments, but probably a continuation of the underlying clays (7.2 m). Using the presence of arenaceous foraminifera in the clay shale unit Ludbrook determined a Lower Permian (Sakmarian) age and a marine influence in the environment of deposition for at least the upper part of the sequence. Harris (1971)⁵ carried out a further stratigraphic study of Ludbrook's type section. It is apparent from his descriptions that the "tills" do not appear to have the characteristics of true lodgement till particularly in his second unit. From the base upwards, Harris (1971) interprets the sediments as: (1) diamictite: clay matrix with large erratics (6.7 m); (2) slumped till with slump rolls of sandstones (1.5 m); (3) boulder beds in sands, claystones and cross-bedded sands (3.9 m); (4) claystones and sand beds with prominent yellow Fontainebleau sandstone, pebbly in places (1.5 m); (5) well laminated grey clay containing arenaceous foraminifera and

dispersed erratics (9.0 m); and (6) poorly exposed but probable boulder clay at surface (exceeds 7 m).

Methods

Despite their great antiquity, the general un-lithified nature of the Late Palaeozoic sediments in South Australia permits the use of techniques normally employed on Pleistocene glacial deposits. Pebble counts of clasts greater than 5 mm diameter have been undertaken to characterise individual tills and to indicate the possible provenance of the clasts. Although some doubt exists about the statistically acceptable number of pebbles required to adequately characterise sediment lithologies, for each lithostratigraphic unit, we have used the usually acceptable minimum population of 300 (Dryden 1931; Krumbein & Pettijohn 1938; Hubert 1971). Till fabric analysis was utilised, in the absence of small scale erosional features, to determine the direction of ice movement. This technique has also served as an aid in establishing the origin of certain diamictites and at Cape Jervis helped to distinguish lodgement and flow tills.

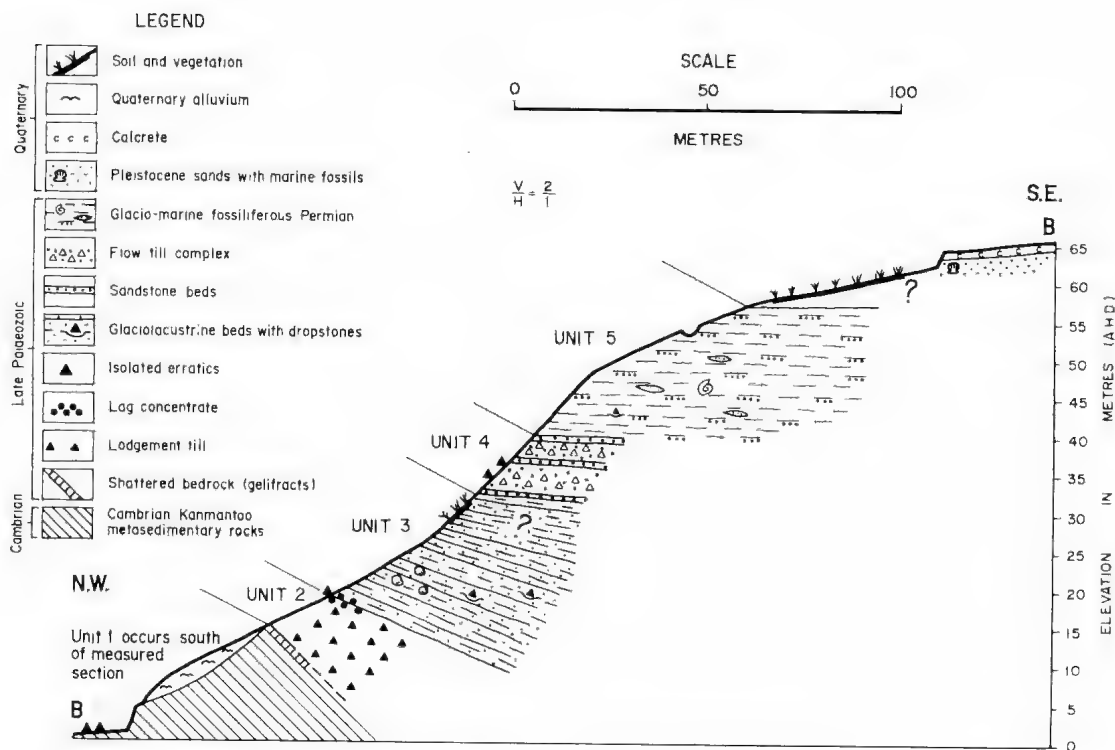
Till fabric analysis rests on the assumption that the long axes of certain pebbles reflect the direction of ice flow at the base of the glacier during their deposition (Holmes 1941). The orientation of a minimum of 50 pebbles represents a statistically acceptable population (Harris 1969; Lindsay 1970). Pebbles selected for analysis were larger than 1 cm and were characterised by the ratio between a and b axes being 3:2 or greater. Results were plotted on rose diagrams in 20° classes since this range best reflects the level of accuracy of both the measurement and the relationship of the long axis to the direction of ice movement.

Stratigraphy of the Type Section

A measured section was examined in a gully which heads in an earth dam immediately north of a fence line in the northern part of the type area (Figs 1, 2). This gully presents the best continuous exposure of the Cape Jervis Beds, and reveals a sequence of older glaciogenic sediments not present in the original measured section which lies several hundred metres to the south of our site (Ludbrook 1967, 1980 p. 76). All other exposures in the outcrop were also examined.

The Cape Jervis Beds have been divided into five units on the basis of sedimentological and genetic differences. We interpret the

⁵ Harris, R. P. (1971) The geology of Permian sediments and erratics, Froumbidge Basin, South Australia. B.Sc. Hons. thesis, Univ. Adel. (unpubl.).



Note For location of measured section see FIG 1

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Fig. 3. Stratigraphy of Cape Jervis Beds at measured section. Unit numbers equivalent to those in text.

sequence to comprise, from the base up, fluvio-glacial and glaciolacustrine sediments, lodgement till, fluviolacustrine deposits, flow till complex and a glaciomarine unit (Fig. 3).

These sediments are in part plastered unconformably against a steep, irregular bedrock slope, and elsewhere occupy north-trending bedrock depressions. These depressions are strongly influenced by the northerly strike and 45°E dip of the bedrock of Cambrian Kanmantoo Group metasediments.

Unit 1—Basal fluvio-glacial and glacio-lacustrine sediments

The base of the measured section comprises approximately 50 cm of angular rubble derived from fracturing of the underlying bedrock. Since excavation revealed that the rubble continues under Unit 2, it is interpreted as frost shattered rock debris (gelifracts) which probably formed in a periglacial environment prior to the advent of ice in the area.

At some other places, Unit 2 directly overlies non-shattered bedrock but attempts to locate buried striated bedrock surfaces by excavating till along the contact were unsuccessful.

At a few other exposures south of the measured section, Unit 2 unconformably overlies a few metres of cross-bedded medium sands at the base, overlain by level bedded, indurated medium to fine sandstone and finely bedded clays. The upper two intervals are characterised by striated dropstones and thin lenses (30–40 cm) of diamicton. Since there is a pronounced erosional surface at the contact with the overlying till unit, the basal beds were probably more extensive than their present meagre outcrops.

The basal beds are interpreted as a proglacial facies of an advancing ice-mass. The cross-bedded sands are probably outwash, whereas the finely bedded clays were possibly

deposited in a small lake dammed between the ice and the steep bedrock slope. Dropstones are thought to have been derived from floating ice, and the diamicton from icebergs or the adjacent glacier.

Unit 2—Lodgement till

Directly overlying the rock rubble at the measured section are 3 m of compact, non-stratified diamicton containing pebbles and boulders of various shapes, sizes and lithologies (Fig. 4a). The larger clasts are commonly polished, faceted and striated. These are set in a matrix of sandy silt. The diamicton is essentially unbedded but at a few sites incorporates small lenses of coarse sand, which may be remnants of deposits from subglacial melt-water channels or the remains of blocks of frozen pre-till sediments eroded by the glacier. Approximately 50 cm of pebble and cobble gravel forms an irregular layer on the upper surface of the diamicton (Fig. 4b).

The diamicton is interpreted as a lodgement or basal till (an interpretation further supported by the till fabric analyses discussed below) and the thin uppermost gravel layer as a lag concentrate formed by erosion of the fines from the till during deglaciation.

The till varies in thickness across the exposure, reaching a maximum of 5 m at one site. On the southern part of the exposure the till is plastered on a steep, channelled bedrock slope; it is evident that the sub-till topography is very irregular (up to 40 m of relief) and that the till locally occurs at a topographically higher level than stratigraphically younger sediments.

Till fabric analyses undertaken at the measured section (site 1) and at a site on the southern part of the type exposure (site 2) reveal a strong NNW-SSE orientation (Fig. 5).

Generally, the till at our measured section contains a low frequency of pebbles (Fig. 4c). Pebble lithologies (Table 1) indicate that the larger clasts are dominantly metasandstones and were probably derived from local Kanmantoo Group bedrock. Clasts of Encounter Bay type granites are present in low frequencies and form some of the larger erratics scattered across the exposure. The Encounter Bay Granites have a broad distribution between Port Elliot (Fleurieu Peninsula) and Cape Willoughby, Kangaroo Island (Daily *et al.* 1979) and were probably more widely

exposed prior to the Late Palaeozoic glaciation. Together with the strong NNW-SSE orientation of the till fabrics, the presence of erratics of the Encounter Bay Granites, implies a local ice movement from the SSE. Pebbles of unknown provenance (not apparently derived from the bedrock on Fleurieu Peninsula or adjacent islands) are represented by

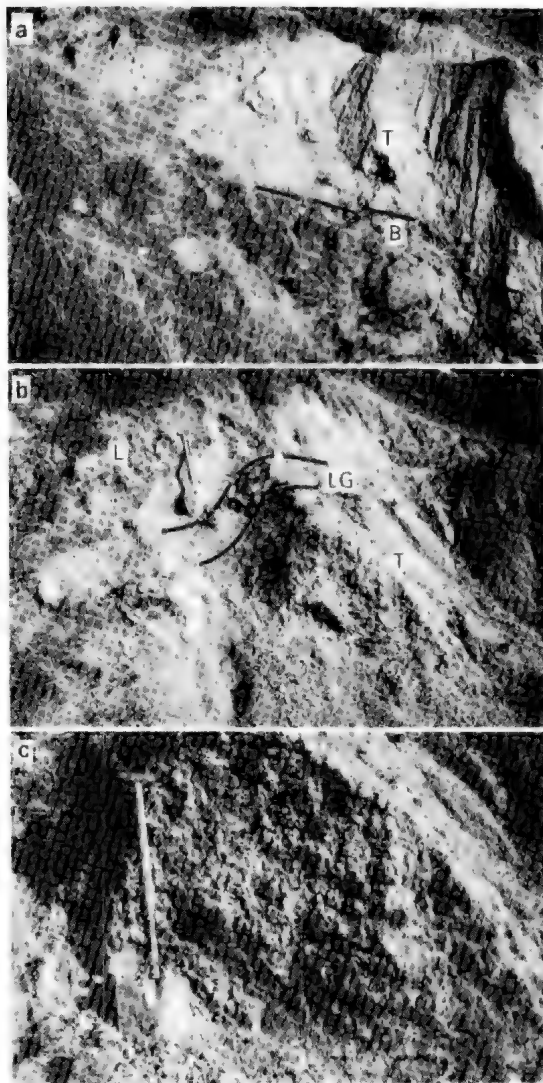
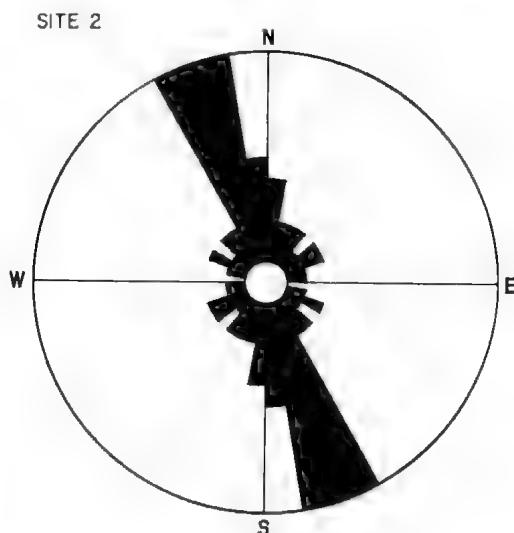
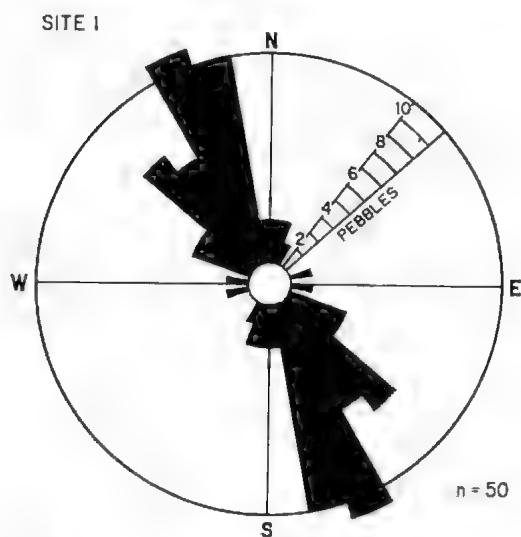
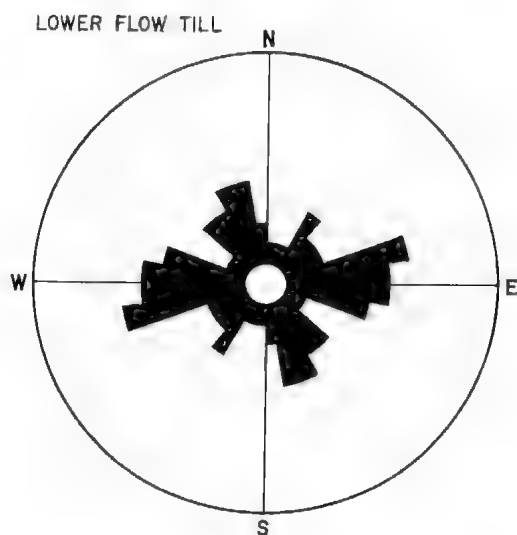
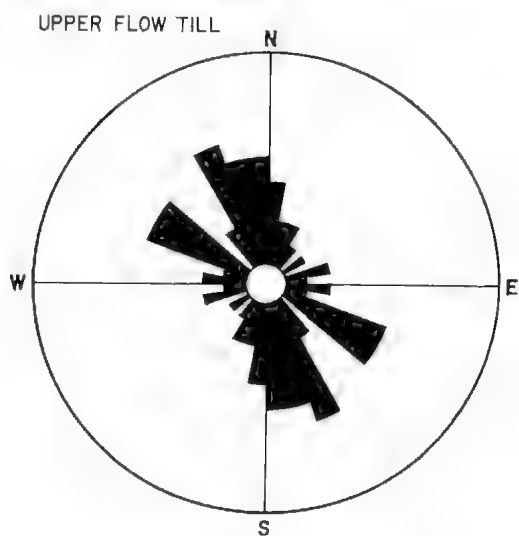


Fig. 4. Units at base of Cape Jervis Beds: a. Frost shattered bedrock (B) overlain by lodgement till (T). View looking southeast. b. Lodgement till (T) overlain by irregular layer of lag concentrate (LG) and fluvio-lacustrine beds (L). Small spade 75 cm long; looking south. c. Close-up of lodgement till showing low frequency of pebbles and cobbles. View looking south.

LODGEMENT TILL FABRICS



FLOW TILL FABRICS



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Fig. 5. Fabrics of lodgement till and flow tills.

low percentages of granitoid types, porphyritic volcanics and pink, micaceous quartzite. The porphyritic volcanics were probably derived from the Mount Monster porphyry in the South East of the State.

Unit 3—Fluviolacustrine beds

Overlying the lodgement till are 15–20 m of interstratified sands, silts and clays containing lenses of gravel and isolated pebbles and

boulders (Figs 6a, b, c). Above these beds are 10–12 m of sediments that are largely obscured with debris and soil in the measured section. However, exposures in adjacent gullies indicate that the unit probably extends up to the base of the flow till complex (Unit 4).

Although the beds are variable in lithology, cross-bedded sands dominate in the lower part of the unit and finely-bedded silt and clay

TABLE 1. *Pebble lithologies of lodgement till (LT) and flow (FT) at Cape Jervis. Figures are percentages of total for each sample of 300; less than 1 percent shown by x.*

Pebble lithologies	LT samples		FT samples	
	1	2	1	2
Meta-sandstone	61	74	75	62
Arkosic sandstone	—	2	1	x
Quartzite				
• Undifferentiated	20	5	4	14
• Pink	3	2	2	4
Siltstone	1	—	x	x
Clay nodule	x	x	—	x
Chert	x	x	x	x
Schist	x	2	1	1
Phyllite	—	4	2	2
Gneiss	—	1	x	—
Quartz	1	2	3	x
Granitoid types	7	7	8	13
Volcanics	—	x	x	x

beds are more common nearer the top. Prominent beds of calcareous sandstone containing pebbles crop out at several intervals; these vary from coarse, well consolidated sandstone to fine friable sand. Rounded to angular intra-clasts of lacustrine clay occur throughout the unit and occasionally form thin lenses. Although such clasts are found in a variety of sedimentary environments, here they were probably eroded from frozen sediments and transported rapidly in a frozen condition to be re-incorporated into adjacent sediments.

Near their base the beds dip eastwards at 15–20° into the underlying bedrock palaeo-slope. Since there is no evidence of similar tilting of units above and below these beds, the tilting could be the result of sub-aqueous slumping, which may have occurred shortly after deposition.

Polished, faceted and striated pebbles are common; stones in the finest beds that penetrate to subjacent layers are regarded as drop-stones. Pebble lithologies are dominated by rocks of local origin although granitoid erratics (including Encounter Bay type) are not infrequent.

Because of the highly variable character of the beds and the presence of glacial erratics and dropstones, the unit is interpreted as of fluviolacustrine origin deposited in close proximity to ice. The beds are characteristic of ice-

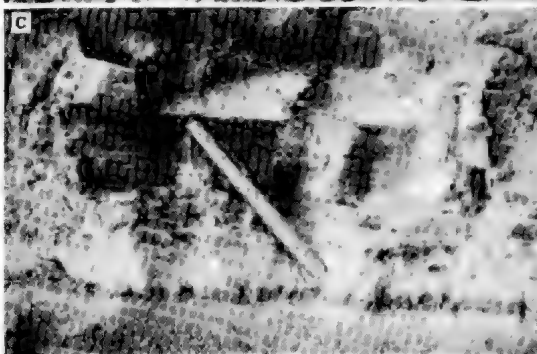
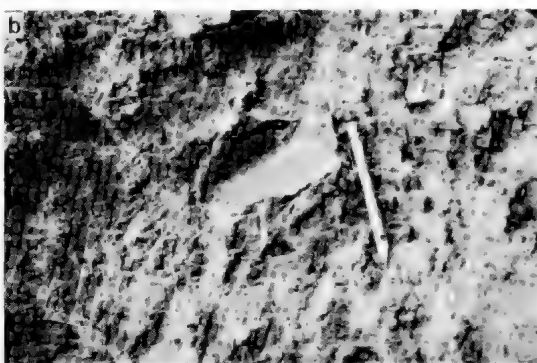


Fig. 6. Fluviolacustrine beds:

- Interbedded sands, silts and clays showing eastward dip.
- Dropstone in bedded silts and clays. Hand lens approximately 135 mm long.
- Finely bedded clays interbedded with medium sands.

contact environments where disintegrating ice produces temporary lakes and meltwater streams, the positions of which are constantly changing (Flint 1971 p. 184). Possibly the ice which deposited the lodgement till lay disintegrating against the bedrock slope thereby damming meltwaters and forming a kame terrace.

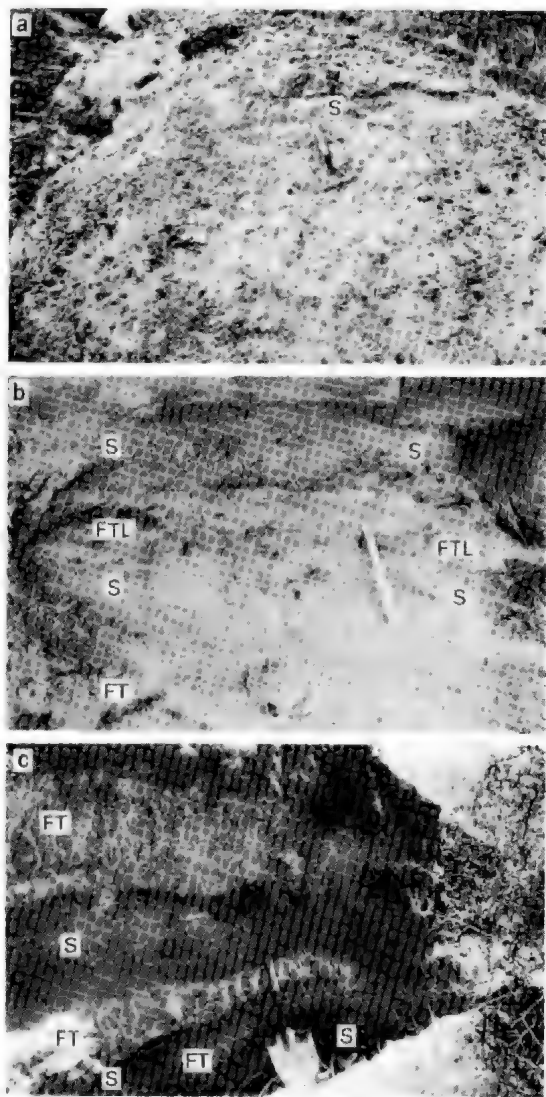


Fig. 7. Flow till complex:
 a. Pebbly and bouldery lower flow till bed. Small lenses of bedded sands (S) near hammer handle. View looking east.
 b. Thin lens of flow till (FTL) interbedded with medium/coarse sands (S) overlying the upper flow till bed (FT). View looking east.
 c. Three flow till beds (FT) intercalated with pebbly medium/coarse sands (S). Lower flow till beds pinch out to right. View looking south.

Unit 4—Flow till complex

Overlying Unit 3 are 8–10 m of sediment consisting of two very pebbly and crudely stratified diamictons intercalated with hard, superficially calcareous, bedded sandstones and other minor bedded silts and clays (Figs 7a, b). The sandstones are the Fontainebleau sandstones of Harris (1971)⁵, although our work reveals that in places the calcareous cement is found only in the outer 50 cm of the exposed rock and is not present at depth. This suggests that the calcification may be the result of relatively recent pedogenic processes.

The matrix of the diamicton beds is a silty sand; it is thus coarser than the matrix of the lodgement till. Gravel and sandy lenses occur in the diamictons, and the larger clasts range in shape from angular to rounded and are commonly striated, polished and faceted. This unit is characterised by a concentration of very large boulders, one measuring 1.5 m diameter. This concentration of boulders is a most striking feature of the type area and is readily traceable across the exposure (Fig. 2). Fabric analyses of the lower and upper diamicton beds reveals chaotic pebble alignments, when compared with the analyses of the basal tills. However, the lower diamicton displays a poor east-west alignment and the upper diamicton, a crude NW-SE alignment (Fig. 5). Pebble lithologies are dominantly local bedrock types but with a slightly higher frequency of granitoid erratics than the lodgement till (Table 1). Harris (1971)⁵ made a detailed lithological study of erratics from till at Cape Jervis, but from his descriptions of the stratigraphy of the site we conclude that the erratics were obtained from the flow till complex (see Fig. 9). The study, however, provides valuable information on the lithology of those distantly derived erratics found in the flow tills.

The sandstones interstratified with the diamictons contain numerous pebbles and thin lenses of fine gravel and grit. The sandstones are both flat- and cross-bedded, and the bed immediately below the lower diamicton is contorted. The shape, surface features and lithologies of the larger clasts within the beds are similar to those in the diamictons.

Exposures in adjacent gullies reveal that similar suites of diamicton beds and associated sediments occur. In a gully immediately south of our measured section a diamicton bed forming part of such a suite was observed to pinch out in a coarse sand bed (Fig. 7c). Elsewhere,

fewer sandy diamictons were found, thus suggesting that the diamicton unit consists of a number of individual tabular lenses.

The diamictons are interpreted as flow tills on the basis of the above evidence and the association with underlying ice-contact sediments. These tills are believed to form in a variety of ways. Most commonly they develop by movement of supraglacial debris from the glacier onto adjacent proglacial sediments or by underwater flows in lacustrine or marine conditions (Dreimanis 1976). Flow tills are generally regarded as indicative of deglacial or ice-stagnation conditions.

The characteristics of the flow tills described above are similar to those of Pleistocene age documented at a number of sites in the Northern Hemisphere. Where successive mudflows have moved from glaciers out over proglacial sediments, flow tills are often interbedded with stratified drift and resemble multiple lodgement tills produced by successive glacial advances (Boulton 1968, 1972). Since flow tills are derived from supraglacial debris, much of the fine clay and silt material is washed out so that the matrix is commonly sandier than that of lodgement tills (Dreimanis 1976, Evenson *et al.* 1977, Hicock *et al.* 1981). Pebble fabrics are found to be random, or unrelated to the direction of glacier movement (since pebble orientation is destroyed during flow from the glacier), or a preferred orientation may be developed in the direction of the mudflow (Marcussen 1975, Dreimanis 1976; Evenson *et al.* 1977, Haldorsen & Shaw 1982). Mud flows may also produce intra- and interformational fold structures and shear planes (Dreimanis 1976, Evenson *et al.* 1977, Hicock *et al.* 1981). Some researchers also find that flow till, because it is derived from supraglacial debris, contains more distal to intermediate clast lithologies, whereas lodgement tills contain mostly local stones (Marcussen 1975, Hicock *et al.* 1981).

The flow till complex in the Cape Jervis section is thought to have formed by successive supraglacial debris flows from ice stagnating in the present Backstairs Passage area. These flows spread out over an adjacent kame terrace thereby blocking streams to form shallow, ephemeral lakes. Fabrics suggest that the lower flow till may have formed by debris flows that moved eastward from the ice and the upper flow till by a northwestward movement of debris.

Unit 5—Glaciomarine sediments

Overlying the flow till unit are at least 14 m of fine silts and clays which were measured up to the small dam at the top of the gully. Sporadic exposures above this level elsewhere indicate that the clays probably extend for

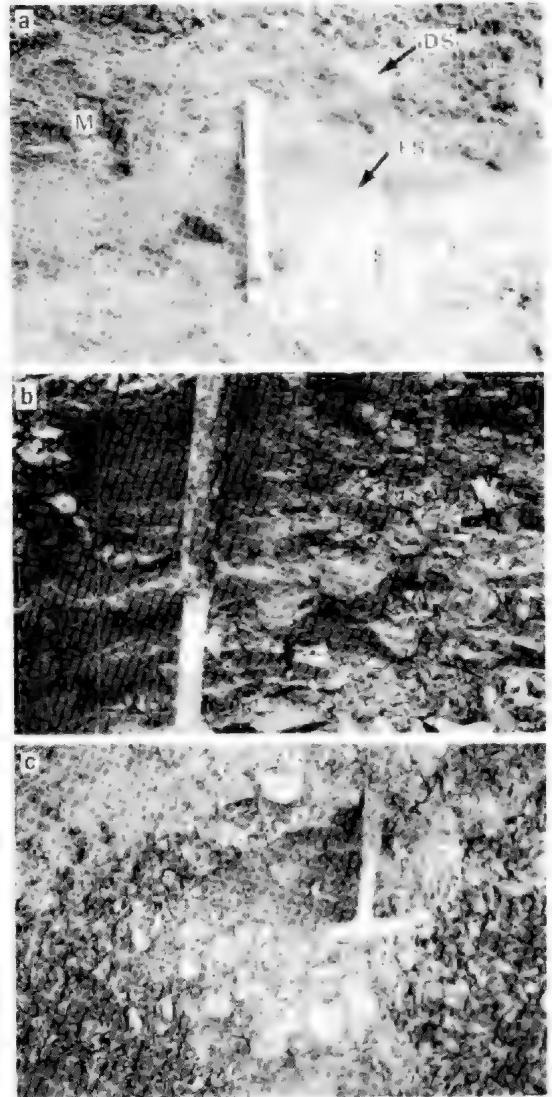


Fig. 8. Glaciomarine beds:

a. Contact between bedded sands (S) of flow till complex and overlying massive glaciomarine silts and clays. Contact characterized by low amplitude flame structures (FS). Drop-stone (DS) also shown. View looking south-east.

b. Horizontally bedded clays of upper part of glaciomarine unit.

c. Plan view of bedding plane showing development of biscuit-shaped joint blocks characteristic of upper glaciomarine clays.

another 30 m. The clay unit is capped by massive calcareated Point Ellen Formation of Ludbrook (1983). Ludbrook (1967) determined a Lower Permian (Sakmarian) age for the clays and the underlying sediments from the presence of marine foraminifera in the clay unit.

At the base of the unit the silty clays are massive and display conchoidal fracturing (Fig. 8a). This part of the unit also incorporates thin beds of sand exhibiting slump structures, and thin lenses and blebs of sand and gravel composed of a variety of lithologies, including some granitic types. A few of the pebbles in the gravel and isolated pebbles in the clay are polished, faceted and striated and are clearly of glacial origin.

The silty clays are conformably overlain by 3–4 m of bedded clays containing pebbles, nodules of sand and numerous very thin lenses of sand or grit measuring at most 10 cm in length. Deformation of the clays under the pebbles and gravel lenses indicate that the coarser clasts in the lower parts of the clayey unit are of ice-rafted origin.

The remaining part of the unit consists of horizontally bedded clays containing dropstones and occasional thin lenses of grit (Figs 8b, c). Generally, the bedding becomes better developed higher in the sequence but there is no evidence that the beds are rhythmites. Numerous pebbles and boulders are strewn across the surface near the upper part of the beds and make the clays there appear till-like. The resemblance is only superficial, however, because the larger clasts are a lag derived from the clays by constant erosion of the slope.

The sedimentary characteristics of this unit and the presence of arenaceous foraminifera suggests that deposition at first occurred in shallow marine conditions in close proximity to ice and meltwater streams. This was followed by deposition in progressively deeper water further away from the influence of the glacier and icebergs. Marine foraminifera recovered from the clays are indicative of low temperatures or low salinity (Ludbrook 1967) which would be consistent with expected influxes of meltwater into a transgressing sea around a stagnating ice-mass.

Relationship to the type section

Although the stratigraphy we present above appears to differ significantly from that of

Ludbrook (1967) and Harris (1971)⁵, it is only because the gully we examined contains a more extensive record of glaciogenic sediments. In the case of the type section, the base is located on portion of a bedrock palaeoslope that stands some 20 m above the base of the section we describe. We believe that the bedrock topography influenced the deposition and preservation of the lower beds, and that the base of the type section and the section described by Harris (1971)⁵ corresponds with the flow till complex (Unit 4) of this paper (Fig. 9).

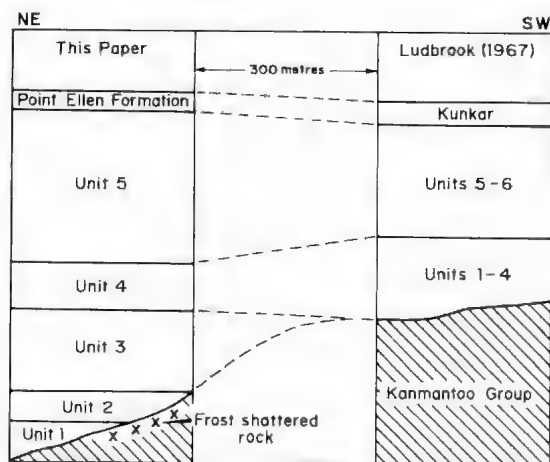


Fig. 9. Diagram showing probable stratigraphic relationships between units in this paper and those of Ludbrook (1967).

Discussion and Conclusions

Ice movements

Evidence presented from areas adjacent to Cape Jervis indicates that movement of Late Palaeozoic ice was generally westward over Fleurieu Peninsula (Fig. 10). Till fabric data at Cape Jervis, however, show that local ice movement was NNW, and it is likely that this was related to the orientation of the bedrock controlled palaeoslope. Similar controls over local ice movement have also been suggested at Hallett Cove to the north of the study area (Sprigg 1945; Milnes & Bourman 1972). Local deviations from the general direction of movement of large masses of ice are commonplace for the Pleistocene ice-sheets in the Northern Hemisphere.

Striae on the western side of Backstairs Passage at Smith Bay, Kangaroo Island, are used to infer a northward direction of ice movement (Daily *et al.* 1979). The fabric of

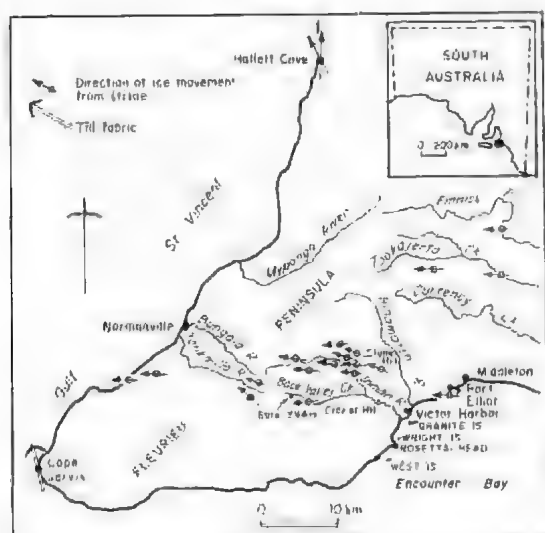


Fig. 10. Map of ice movement across Fleurieu Peninsula as derived from striae. Source: Sprigg (1945), Milnes & Bourman (1972), Bourman & Milnes (1976) and Bourman *et al.* (1976).

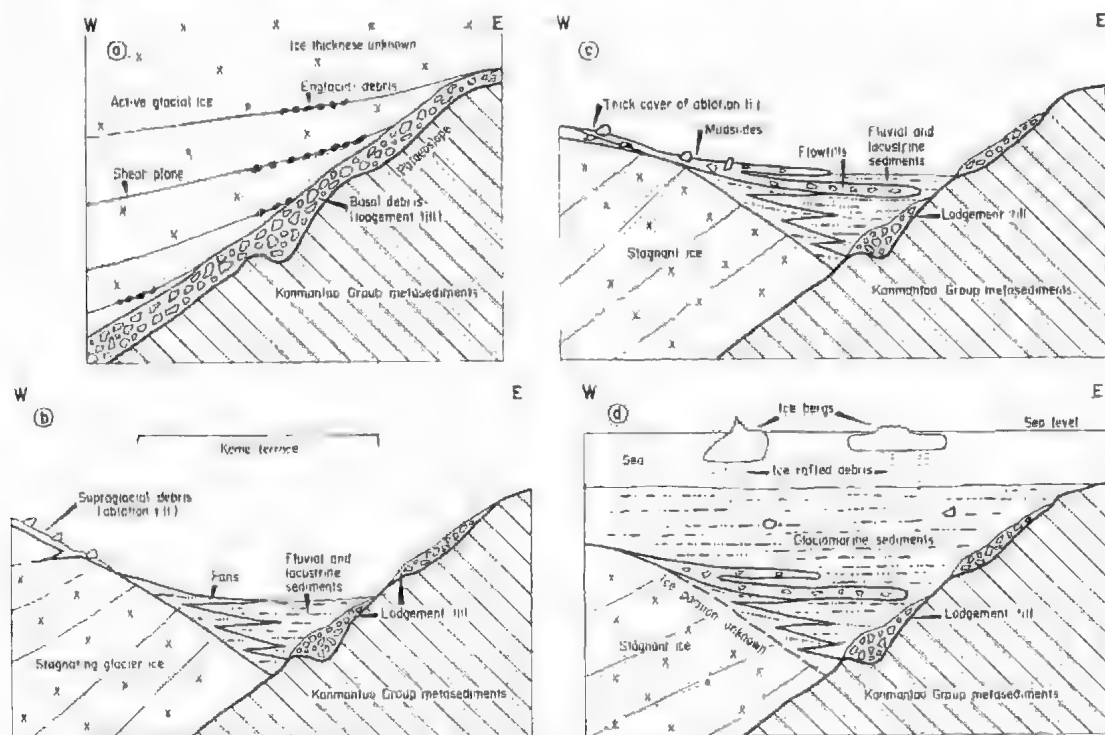
the lodgement till overlying this striated bed-rock surface showed a north-south alignment

of pebbles which is consistent with such movement.

We conclude from the above evidence that movement of ice across Fleurieu Peninsula was essentially westward but locally in the Cape Jervis area was guided by a north-south trending depression. It is possible that Cape Jervis lay in close proximity to the confluence of ice flowing westward across Fleurieu Peninsula and ice moving northward along the eastern side of the modern Gulf St Vincent.

Model of deposition

The conclusions drawn concerning the genesis of the major facies comprising the Cape Jervis Beds are summarised in Figure 11. This depositional model is characteristic of large ice-masses stagnating in coastal lowlands (Alley & Chatwin 1979). During deglaciation, retreat of the ice margins is accompanied by general down-wasting of the ice surface. Uplands emerge through the ice first as it wastes down into the major valleys and coastal troughs where it may remain covered and protected by supraglacial debris for a considerable time. In these situations the stagnant



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Fig. 11. Model of deposition for Cape Jervis Beds at Cape Jervis.

ice dams meltwaters and streams flowing from the uplands against the adjacent slopes. The ice marginal zones then become elongate basins in which complex suites of ice contact and proglacial sediments are deposited.

Deposition in coastal areas is usually complicated by late deglacial transgression of the sea over and around the stagnating ice. For a short period there is an apparent rapid glacio-eustatic rise in sea level since this outstrips the rate of isostatic recovery in the lowland areas where rebound is slowed by the presence of thick masses of stagnating ice. With large volumes of meltwater and glacial debris available, a considerable thickness of sediment may be deposited in relatively deep, brackish-water conditions.

In summary, our model for deposition of the Cape Jervis Beds comprises the following:

- (1) Lodgement till was laid down over remnants of proglacial sediments or plastered on a partly frost-shattered, irregular west-facing slope by glacier ice moving roughly from south to north (Fig. 11a).
- (2) Deglaciation led to ice stagnation during which ice down-wasted into the coastal trough, exposing first the uplands and then the lodgement till on the palaeoslope. A kame terrace formed between the ice and adjacent slope. The terrace initially consisted of a complex suite of interfingering alluvial and lacustrine sediments (Fig. 11b).
- (3) Further down-wasting of the ice led to the development of a thick cover of supraglacial debris which, from time to time, became unstable enough to flow from the ice out across the adjacent kame terrace, thus forming a series of flow till beds (Fig. 11c).
- (4) Eustatic rise in sea level led to a rapid marine transgression that submerged the slope and probably part of the stagnant ice in the trough. Subsequent sedimentation occurred in brackish water turbid with fines brought to the sea by abundant meltwater, while lenses of coarser clasts and isolated pebbles/boulders were dropped from icebergs into the finer sediment below (Fig. 11d).

Conclusions

Our examination of the thickest and most continuous exposure of the glaciogene Jervis Beds suggests that the sediments are related to only one glacial advance. All of the characteristics of the sediments can be accounted for in terms of deteriorating climatic conditions preceding glaciation, the passage of a wet-based (temperate) glacier over the site, and various proglacial environments associated with the stagnation and decay of an ice-mass. Although at least four till-like deposits occur in the type area, only one can be identified as a lodgement till. Hence, this site presents no evidence, at least locally, for multiple glaciation in the Late Palaeozoic.

Finally, our studies reveal that the sediments from which the Permian age of the glaciation is determined represent the final deglacial episode and are the youngest part of the Cape Jervis Beds. Whether the underlying beds are earliest Permian in age or older however, could not be determined.

Acknowledgments

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ASPECTS OF GENETIC RELATIONSHIPS AND VARIATION IN PARROTS OF THE CRIMSON ROSELLA PLATYCERCUS ELEGANS COMPLEX (AVES: PSITTACIDAE)

BY LEO JOSEPH & RORY HOPE

Summary

Enzyme electrophoresis was used to examine genetic variation within and between three of the four principal parrot taxa of the Crimson Rosella taxa of the *Platycercus elegans* complex of eastern Australia. Comparisons were made with the results of recent studies of other birds, mainly Northern Hemisphere members of the Order Passeriformes in which it has been shown that although populations of birds show levels of variation in isozymes comparable with those in other vertebrates, levels of isozymic differentiation and thus structural gene differentiation between bird taxa are unusually low. The data from rosellas, which belong to the Order Psittaciformes, although necessarily limited and therefore somewhat equivocal with respect to these generalizations, appear to be consistent with them, especially the former. No significant or consistent geographical patterns of gene frequency differences were detected among the rosellas studied.

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JOSEPH, L. & HOPE, R. (1984). Aspects of genetic relationships and variation in the parrots of the Crimson Rosella *Platycercus elegans* complex (Aves: Psittacidae). *Trans. R. Soc. S. Aust.* 108(2), 77-84. 12 June, 1984.

Enzyme electrophoresis was used to examine genetic variation within and between three of the four principal parrot taxa of the Crimson Rosella *Platycercus elegans* complex of eastern Australia. Comparisons were made with the results of recent studies of other birds, mainly Northern Hemisphere members of the Order Passeriformes in which it has been shown that although populations of birds show levels of variation in isozymes comparable with those in other vertebrates, levels of isozymic differentiation and thus structural gene differentiation between bird taxa are unusually low. The data from rosellas, which belong to the Order Psittaciformes, although necessarily limited and therefore somewhat equivocal with respect to these generalizations, appear to be consistent with them, especially the former. No significant or consistent geographical patterns of gene frequency differences were detected among the rosellas studied.

KEY WORDS: Birds, electrophoresis, population genetics, *Platycercus elegans*.

Introduction

Four principal parrot taxa comprise the Crimson Rosella *Platycercus elegans* complex in eastern Australia (see Fig. 1a and Forshaw 1981, for details of habitat and distribution). One, the Crimson Rosella *P. elegans*, ranges south from the Atherton Tableland, Queensland, along Australia's eastern coast to south-eastern South Australia with an isolated population on Kangaroo Island. Adults are predominantly crimson, immatures green. A second, the Yellow Rosella *P. flaveolus*, is confined to the Murray-Darling river system. In general, the crimson in the plumage of *P. elegans* is replaced by yellow in this form. In the Mt Lofty Ranges and southern Flinders Ranges there occurs a third form, a series of populations all of which are variable in colour but intermediate between *P. elegans* and *P. flaveolus*. These are collectively termed here the Adelaide Rosella *P. adelaidae*. There is clinal variation in plumage in *P. adelaidae*, particularly on the ventral surface (Forshaw 1981). In the southern Mt Lofty Ranges adults are, generally, rich scarlet. Northwards, they become progressively lighter and more orange. Populations in the Flinders Ranges are predominantly yellow ventrally but usually have a strong wash of orange. The fourth member of the complex, the Green Rosella *P. cal-*

donicus of Tasmania and the larger Bass Strait islands, was not included in this study.

There has been considerable debate over the relationships and taxonomic status of these parrots. Condon (1954) proposed that *P. adelaidae* evolved through hybridization between *P. elegans* and *P. flaveolus*. This is suggested by the intermediate colouration of *P. adelaidae* (see also Martindale 1974¹, Forshaw 1981). Also, the south-north cline in colouration of *P. adelaidae* is most simply explained perhaps as having arisen through introgression of *P. flaveolus* genes from the north and *P. elegans* genes from the south. If so, this would afford further support for some previous hybridization, Cain (1955) and Keast (1961), on the other hand, suggested that the members of the complex evolved *in situ* in response to climatic changes.

Two generalizations have emerged from recent electrophoretic studies of genic variation in birds. Firstly, populations of birds do not differ significantly from those of other vertebrates in levels of within-population variation. Secondly, there seems to be considerably less genic differentiation between bird taxa than

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¹ Martindale, J. (1974). Some ecogenetic relationships and their origins in platycercine species complex (Order Psittaciformes, Class Aves) of south-eastern Australia, Honours Thesis, Department of Genetics and Human Variation, La Trobe University, Victoria. Unpubl.

between taxa of other vertebrate classes at equivalent levels of the taxonomic hierarchy (see, for example, Avise & Aquadro 1982 and references therein and an alternative view offered by Sibley & Ahlquist 1982).

These generalizations have grown largely out of studies of passerine birds. Concerning Australian species, data are at present available only for the Grey-crowned Babbler *Pomatostomus temporalis*, a communally breeding passerine, and from some species of the passerine family Hirundinidae (Johnson & Brown, 1980; Manwell & Baker, 1975). Thus, the present study of non-passerine birds aimed (1) to measure levels of electrophoretically detectable genic variation between and within some members of the Crimson Rosella complex, and (2) to compare them with such levels measured in other birds and vertebrates in general.

Materials and Methods

Collecting Procedures: Specimens of rosellas were collected under a permit from the South Australian National Parks and Wildlife Service. Within an hour of death, samples of liver, heart muscle and breast muscle were extracted for electrophoresis and transported in dry ice to the laboratory where they were stored at -20°C . Specimens were sexed by dissection and aged as adult or immature from plumage (Lendon 1973). Stomach contents have been preserved and the birds have been prepared as voucher study skins and lodged in the South Australian Museum, Adelaide. The collecting localities are shown in Fig. 1b.

Adelaide Rosella *P. adelaidae*: 59 specimens were collected to sample *P. adelaidae* as evenly as feasible throughout its range. They were collected in six geographical sectors: S, extreme southern Mt Lofty Ranges =

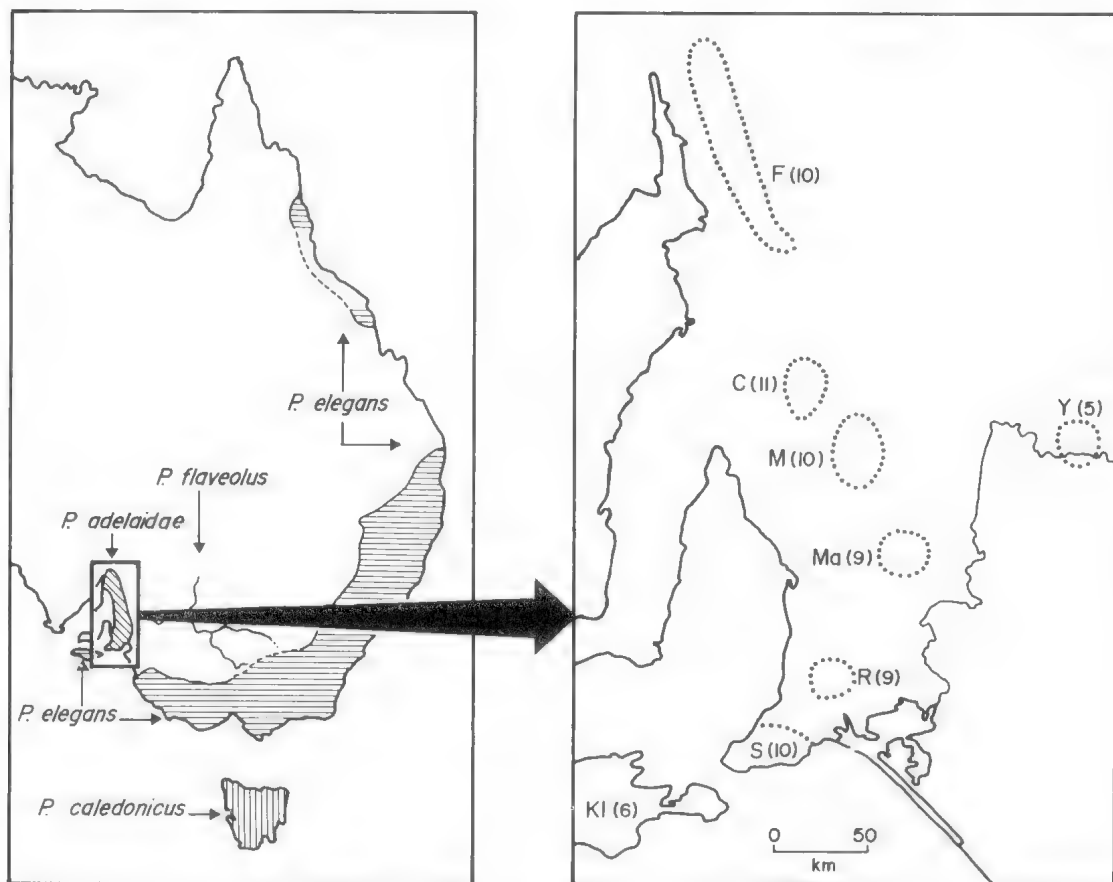


Fig. 1. (a) Approximate distribution of members of the *P. elegans* complex in eastern Australia. (b) Localities and sample sizes collected for this study; letters are the abbreviated names of each sample.

Fleurieu Peninsula (10 specimens); R, southern central Mt Lofty Ranges between Ashbourne and Meadows (9); Ma, lower Marne River and environs (9); M, northern central Mt Lofty Ranges between Kapunda and Saddleworth (10); C, northern Mt Lofty Ranges between Auburn and Clare (11); and F, southern Flinders Ranges between Jamestown and the Dutchman's Stern (10). No more than three specimens were taken from one locality within these sectors with the exceptions of 15 km NE of Saddleworth and the Dutchman's Stern. Sample F was taken over a larger area than the other samples because of the logistic difficulties involved in sampling the Flinders Ranges birds and because it was intended to treat these birds as a distinct sub-population of *P. adalaidae* in subsequent data analyses.

Crimson Rosella *P. elegans*: six specimens were taken from four localities at the western end of Kangaroo Island. In addition, the livers of four from the South-East of S.A. and of six from the Atherton Tableland, Qld were examined. Voucher specimens of the latter two samples are held in the Australian National Wildlife Collection, Canberra.

Yellow Rosella *P. flaveolus*: five specimens from near the Murray River between Barmera and Waikerie were examined.

Other species: organ extracts were obtained from the parrot genera *Barnardius* and *Psephotus*, both of which are closely related to *Platyercus* (Cain 1955) and of a more distantly related bird, a pigeon. Details of these are as follows: the exotic Spotted Turtle-Dove *Streptopelia chinensis* (one individual, liver only, collected in grounds of University

of Adelaide), Mallee Ringneck Parrot *Barnardius barnardi* (two, liver and heart muscle, near Swan Reach), Mulga Parrot *Psephotus varius* (one, liver and heart muscle, near Swan Reach), Red-rumped Parrot *Psephotus haematonotus* (one, liver only, near Mannum). The availability of these samples made possible genetic comparisons between the members of the *P. elegans* complex and other species.

Electrophoresis: Electrophoresis was carried out on cellulose acetate gels (Meera Khan 1971) following procedures of Baverstock *et al.* (1977). When electrophoresis revealed two forms of an enzyme (manifest as distinct sets of bands), the presumptive locus encoding the most anodal form was designated 1 and the other 2 e.g. *Idh-1*, *Idh-2* for isocitrate dehydrogenase. The presumptive allele encoding the most anodally migrating product of a locus was designated *a*, the second most anodal *b* and so on. In one case, *Pgd*, *b'* indicates an allelic form of the enzyme intermediate in mobility between *Pgd^b* and *Pgd^c*.

Table 1 shows the enzymes assayed and the organ and electrophoresis buffer used for each enzyme. In all, nine enzymes were electrophoresed and choice of these was not entirely random, being determined partly by which enzymes were under investigation in the laboratory for other projects. Aconitase was examined to test a hypothesis of sex-linkage in birds (see Baverstock *et al.* 1982).

The symbols used to represent the locus or loci corresponding with each enzyme are: 6-phosphogluconate dehydrogenase, *Pgd*; purine nucleoside phosphorylase, *NP*; adenylate kinase, *Ak-1*, *Ak-2*; phosphoglucomutase, *Pgm*; isocitrate dehydrogenase, *Idh-1*, *Idh-2*;

TABLE 1. Enzymes assayed and buffers and organs used for electrophoresis.

Enzyme	Buffer ¹	Organ ²
6-Phosphogluconate dehydrogenase	B + NADP	L
Purine nucleoside phosphorylase	A	L
Pyruvate kinase	C	L, H
Adenylate kinase	B	L
Phosphoglucomutase	C	L
Isocitrate dehydrogenase	B + NADP	L, H
Aconitase	B	L, H
Glucose phosphate isomerase	B	L
Glutamate oxaloacetate transaminase	B	L

¹ Buffer code: A—0.01 M citrate-phosphate, pH 6.4; B—0.02 M phosphate, pH 7.0; C—0.05 M tris-maleate, pH 7.8; D—0.12 M tris-glycine, pH 9.5

² Organ code: L—liver; H—heart.

+ NADP indicates that 600 μ l of NADP (10 mg/ml) were added to the buffer placed in the cathodal compartment and in which the gel was soaked.

aconitase, *Acon-1*, *Acon-2*; glucose phosphate isomerase, *Gpi*, glutamate oxaloacetate transaminase, *Got* and pyruvate kinase, *Pk*.

Analysis of data: The proportion of polymorphic loci, *P*, was calculated directly using two definitions of polymorphism: one where the most common allele had a frequency of less than 0.99 and the other where this frequency was less than 0.95.

The average heterozygosity per locus, *H* (see Nei 1978), was calculated as:

$$H = \frac{\sum h}{r}$$

where *r* is the number of loci scored, and *h* is the expected heterozygosity at each locus, calculated as $1 - x_i$ where x_i is the frequency of the *i*th allele at each locus.

Standard errors of *H* estimates have been discussed by Nei (1978) and Nei & Roychoudhury (1974), who concluded that it is more important when estimating *H* to screen many loci in few individuals rather than the converse. Gene frequencies were compared with

t-tests and Fisher's exact method. So that comparisons could be made between *P. elegans* or *P. flaveolus* on one hand and *P. adelaidae* on the other, the *P. adelaidae* data for each locus were pooled, their homogeneity first being assessed by the method of Hancock (1975). Heterogeneity was detected only for the data from pyruvate kinase, which were accordingly not used in such data analyses.

Results

Electrophoretic Typings and Isozymic Variation within *P. adelaidae*

Tables 2 and 3 present the results of electrophoresis and Table 4 presents measures of genic variation within the rosellas and in vertebrates in general. The standard errors of the rosella *H* estimates are relatively large, e.g. approximately 0.05 for the *H* estimate of 0.104 in *P. adelaidae* (see Nei 1978). The estimates are, therefore, only coarse approximations. The data for *Pgd*, *Np*, and *Idh-2*, the most variable loci, showed *P. adelaidae* to

TABLE 2. Numbers of individuals of indicated genotypes in population samples of the *P. elegans* complex. In samples of *P. elegans* itself, KI = Kangaroo Island, SE — South-East of South Australia, and A = Atherton Tableland, Qld. For brevity, genotypes are represented thus: at an indicated locus e.g. *Pgd*, *a/a* designates *Pgd*^a/*Pgd*^a. Wholly invariant loci are omitted. Heart samples for typing of *Acon-2* and *Idh-2* not available for samples SE and A.

Genotype		<i>P. elegans</i>			<i>P. adelaidae</i>	<i>P. flaveolus</i>
		KI	SE	A		
<i>Pgd</i>	<i>a/a</i>	2				
	<i>a/b</i>		1		10	2
	<i>b/b</i>	4	2	5	39	2
	<i>b'/c</i>				1	
	<i>b/c</i>		1		8	1
	<i>c/c</i>				1	
<i>Np</i>	<i>a/a</i>	5	1	—	29	2
	<i>a/b</i>		3		23	2
	<i>b/b</i>				5	1
	<i>a/c</i>				2	
<i>Ak-1</i>	<i>a/b</i>				1	
	<i>b/b</i>	6	4	6	58	5
<i>Ak-2</i>	<i>a/b</i>	1	1			
	<i>b/b</i>	5	3	6	59	5
<i>Pgm</i>	<i>a/b</i>				1	
	<i>b/b</i>	6	4	6	58	5
<i>Idh-1</i>	<i>a/a</i>			1		
	<i>a/b</i>			2		
	<i>b/b</i>	6	4	0	59	5
<i>Idh-2</i>	<i>b/b</i>				5	
	<i>a/c</i>				2	
	<i>a/b</i>				1	1
	<i>a/a</i>	6			48	4
<i>Acon-1</i>	<i>a/a</i>				1	
	<i>b/b</i>	5			57	5

TABLE 3. Numbers of individuals of indicated genotypes in population samples of *P. adelaidae* designated S, R, Ma, M, C and F (see text). Genotypic symbolism as for Table 2. Wholly invariant loci are omitted.

Genotype		S	R	Sample			F
				Ma	M	C	
Pgd	a/b		3		4	2	1
	b/b	8	5	6	5	6	9
	b'/c		1				
	b/c	2		3	1	2	
	c/c					1	
Np	a/a	6	6	3	6	1	8
	a/b	2	3	5	3	8	2
	b/b	2		1		1	
	a/c				1	1	
Ak-1	a/b				1		
	b/b	10	9	9	9	11	10
Pgm	a/b						1
	b/b	10	9	9	10	11	9
Idh-2	c/a			2			
	b/c			1			
	c/c	7	7	6	10	8	10

TABLE 4. Values of *P*, the proportion of polymorphic loci, and *H*, the average heterozygosity per locus, obtained in the *P. elegans* complex. Values for Vertebrata and Aves are from Nevo (1978).

Taxon	Loci scored	P		H
		Freq. of most common allele		
		<0.99	<0.95	
<i>P. adelaidae</i>	10	0.3	0.3	0.104
<i>P. elegans</i>				
Kangaroo Island	11	0.18	0.18	0.07
South-East	8	0.375	0.375	0.137
Atherton Tableland	8	0.125	0.125	0.05
<i>P. flaveolus</i>	11	0.27	0.27	0.102
Vertebrata	—	0.173 ± 0.119		0.0494
				0.0365
Aves	—	0.150 ± 0.111		0.0473
				0.0360

be in Hardy-Weinberg equilibrium (*Pgd*, $\chi^2_{11} = 0.74$, $0.7 > P > 0.5$; *Np*, $\chi^2_{11} = 0.025$, $0.9 > P > 0.8$; *Idh-2*, $\chi^2_{11} = 2.16$, $0.2 > P > 0.1$).

Two detected alleles were unique to *P. elegans* and six to *P. adelaidae* (Table 2). None occurred at frequencies significantly higher than zero except *Pgm*^a in the comparison of the Flinders Ranges *P. adelaidae* sample with all other samples of *P. adelaidae* pooled together.

Comparisons of Gene Frequencies

Even allowing for the small sizes of the samples, significant differences in gene frequency were few, especially between *P. elegans* and *P. flaveolus*. Atherton Tableland *P. elegans* despite its geographical isolation, differed significantly from *P. flaveolus* and the other

P. elegans samples only in gene frequencies at the *Idh-1* locus. South-East *P. elegans* showed no significant differences from *P. flaveolus*. One significant difference between South-East and Kangaroo Island *P. elegans* was detected at *Np*. The six samples from Kangaroo Island all lacked the *Np*^b and, as well, the *Pgd*^c genes found in *P. flaveolus* and South-East *P. elegans* and also the *Idh-2*^b gene found in *P. flaveolus* and *P. adelaidae*. Only for *Np*^b in the Kangaroo Island *P. elegans*-*P. flaveolus* comparison was such a difference significant ($P = 0.043$).

Pgd^a occurred at a significantly higher frequency in Kangaroo Island *P. elegans* than in *P. adelaidae* samples, S, Ma and F and all *P. adelaidae* samples pooled, and was greater also in *P. flaveolus* and sample M than sample

S. Np^a occurred at a significantly greater frequency in Kangaroo Island *P. elegans* than in *P. adelaidae* samples Ma and C and all *P. adelaidae*.

Within *P. adelaidae*, significant differences in gene frequency were few and showed no consistent geographical pattern. The Flinders Ranges sample of *P. adelaidae* differed significantly from other *P. adelaidae* samples pooled only for *Pgm* ($0.05 > P > 0.02$).

Enzyme Expression

The enzyme products of *Idh-1* and *Acon-1* were strongest in liver extracts, while those of *Idh-2* and *Acon-2* were strongest in heart extracts. *Avisé et al.* (1980) noted the same difference for *Idh* loci in North American thrushes and their allies. Wholly or largely invariant enzymes were both glucose- and non-glucose metabolizing.

Discussion

Although breeding studies in rosellas have not been conducted to test the mode of inheritance of the proteins examined in this study, Mendelian inheritance has been assumed because:

(i) the proteins examined display Mendelian inheritance wherever studied in other organisms (see, for examples, Harris & Hopkinson 1976); and

(ii) population data satisfy Hardy-Weinberg expectations such as to render unlikely any other mode of inheritance approximating Mendelian expectations.

Thus, the isozymic data obtained in this study may be used to discuss genetic relationships and variation.

The sample sizes used in this study, particularly those of *P. elegans* and *P. flaveolus* were rather small. *Baverstock et al.* (1977) have shown nonetheless that such samples can be adequate to indicate relationships in electrophoretic studies, although they did not negate the desirability of having larger samples, especially for studies of within-population variation.

The genic variation measured in the rosellas, genically limited though it is, is consistent with evidence that levels of genic variation in birds are much the same as those in other vertebrates. Similarly, the paucity of genic differentiation between the rosellas may support the concept that in birds morphologically quite different taxa exhibit relatively less structural gene differentiation within an Order than do

other animal groups. Consistent with this were the observations of alleles shared by the parrot genera *Barnardius*, *Psephotus* and *Platycercus*. Nevertheless one should note that although *P. elegans* and *P. flaveolus* appear quite different, there could be a simple genetic basis to their plumage differences. A full discussion of the concept of weak structural gene differentiation in birds is not intended here; the reader is referred to the reviews and alternative opinions presented by Sibley & Ahlquist (1982) and *Avisé & Aquadro* (1982).

If sampling in *P. adelaidae* has been comprehensive, the evolutionary and genetic significance, if any, of 'unique' alleles in *P. adelaidae* shall remain obscure until more extensive samples of *P. elegans* and *P. flaveolus* are collected. Bearing in mind the possibility that *P. adelaidae* evolved by hybridization, we would note that the phenomenon of 'unique' alleles in hybrid populations has been observed previously and discussed by *Golding and Strobeck* (1983).

Some of the differences in gene frequency between Kangaroo Island *P. elegans* and other populations may be due to stochastic effects. This population has been isolated for some 10 000 years (*Lampert* 1979).

Four presumptive pyruvate kinase heterozygotes (double-banded) were detected in liver extracts of *P. adelaidae*. Heart extracts of three of these individuals were found to be single-banded. Possibly, pyruvate kinase is modified in the liver, producing a secondary band on gels, thereby creating a false impression of heterozygosity in homozygotes. Alternatively, a gene for pyruvate kinase may be 'switched-off' in the hearts of rosellas heterozygous for it. Extracts from other organs and analysis of data from parents and their offspring would resolve this anomaly. Almost certainly, this difference explains the statistical heterogeneity in the *P. adelaidae* data for pyruvate kinase.

Relationships in the *P. elegans* species-group

As noted above, *Cain* (1955) and *Keast* (1961) suggested that the members of the *P. elegans* complex evolved *in situ* in response to climatic changes. Alternatively, *Ford* (1977) proposed that *P. flaveolus* originated in the Mt Lofty Ranges while isolated from *P. elegans* by arid country in the region of the Coorong during an arid part of the Pleistocene. According to this interpretation, *P. flaveolus* moved northwards into the Flinders Ranges

and eastwards to the Murray-Darling system when this barrier broke down, while *P. elegans* moved westwards and freely hybridized with *P. flaveolus* in the Mt Lofty Ranges, producing *P. adelaidae*. Although Ford (1977) was able to suggest dates for these proposed events from geological data, one of his postulates, namely that of Flinders Ranges *P. adelaidae* being isolated by seventy kilometres from other populations of *P. adelaidae* to the south, appears to be exaggerated. Any 'isolation' of this population can be by no more than thirty to forty kilometres. Moreover, it is unlikely to be permanent owing to the vagility of rosellas combined with the existence of habitat corridors, and has undoubtedly been promoted by, if it is not entirely consequent upon, agricultural clearing of vegetation in the northern Mt Lofty Ranges within the last 100 years. Thus, given the likelihood of gene flow through all populations of *P. adelaidae*, the mechanism of the maintenance of clinal plumage variation in *P. adelaidae* remains problematic. Neither Hardy-Weinberg equilibria nor regression and correlation analyses suggested that strong selection differentials act on electrophoretic characters in *P. adelaidae*. The existence of some measure of selection is suggested by the clinal variation in plumage itself and by the *Pgm* and *Idh-2* gene frequency differences between the Flinders Range and other *P. adelaidae* samples.

Concerning the relationship between *P. flaveolus* and *P. adelaidae*, Short (1969) argued that it should be determined whether the two overlap with only some hybridization or with extensive hybridization: the former situation would indicate effective reproductive isolation, the latter conspecificity. Unfortunately, the observations and claims of Lendon (1973) and Condon (1969, 1975) concerning overlap between the two lack adequate supporting evidence. Present-day hybridization between them or, more specifi-

cally, introgression of *P. flaveolus* genes into *P. adelaidae* is suggested by the *Idh-2* data. *Idh-2^b* was not detected in *P. elegans* but it was in *P. flaveolus* and several samples of *P. adelaidae*, including that taken from the Marnie River region where *P. adelaidae* and *P. flaveolus* are perhaps closest (unpubl. data). More material would be useful in evaluating this and any other interpretations.

Overall, the genic data indicate a close relationship between the three rosellas studied but at present they are insufficient to determine with certainty whether the birds constitute a single biological species. There is scope for much further work on the group. The mechanism and maintenance of the clinal variation in, and the significance of 'unique' genes in *P. adelaidae* could be clarified with more extensive field and laboratory analyses. Also, the relationship of *P. calendonicus* to the other members of the complex warrants investigation as does a much closer examination of the genetic relationships between all the members. A karyotypic analysis may prove useful, specially to test further the hypothesis of a hybrid origin of *P. adelaidae*.

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COASTAL LANDSLUMPING IN PLEISTOCENE SEDIMENTS AT SELICKS BEACH, SOUTH AUSTRALIA

BY R. I. MAY & R. P. BOURMAN

Summary

A pronounced bench occurs at approximately 25 m asl in a short section of the 50 m high coastal cliffs eroded in Quaternary sediments at Sellicks Beach, South Australia. Below the bench the sediments are disturbed and the stratigraphy is confused. As a result of studies of the regional stratigraphic succession we have identified the presence of a large rotational landslump as well as evidence of earlier phases of slump activity. Here we describe the Late Cainozoic stratigraphic record near Sellicks Trig., the morphology of the bench and the character of the underlying sediments, the probable age of the slumping responsible for the bench and factors involved in its formation, and implications for planning, development and management of this coastal region.

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A pronounced bench occurs at approximately 25 m a.s.l. in a short section of the 50 m high coastal cliffs eroded in Quaternary sediments at Sellicks Beach, South Australia. Below the bench the sediments are disturbed and the stratigraphy is confused. As a result of studies of the regional stratigraphic succession we have identified the presence of a large rotational landslump as well as evidence of earlier phases of slump activity. Here we describe the Late Cainozoic stratigraphic record near Sellicks Trig., the morphology of the bench and the character of the underlying sediments, the probable age of the slumping responsible for the bench and factors involved in its formation, and implications for planning, development and management of this coastal region.

KEY WORDS: Pleistocene stratigraphy, slumping, Sellicks Beach, management.

Introduction

Investigations of the Late Cainozoic stratigraphic succession exposed in the coastal cliffs south of Adelaide are currently being undertaken in the light of previous work in the region (e.g. Howchin 1923, Campana & Wilson 1953, Ward 1966, Cooper 1979) to provide information on the mineralogy, chemistry and environments of deposition of the sediments. About 200 m north of Sellicks Trig. within Section 673, which is designated a Recreation Reserve (Fig. 1), is a bench that has previously escaped notice and comment apart from a possible passing reference by Howchin (1923, p. 310). An understanding of the stratigraphic succession of the Late Cainozoic sediments described by Ward (1966) provides the basis for the interpretation of the structure and its possible age and origin.

Stratigraphy

The oldest rocks at the site of the bench in the coastal cliffs are Miocene limestones of the Port Willunga Formation (Cooper 1979). These rocks, which occur at levels up to 7 m above sea level, have been warped into a slight antiformal structure under the bench. A karst-like and calcreted surface is preserved on these limestones with a vertical relief in excess of 4 m. The presence of silicified plant roots on the calcreted surface indicates the former existence of a soil and prolonged exposure

prior to the deposition of the overlying sediments.

The major part of the cliffs at Sellicks Trig. consists of unconsolidated Late Cainozoic mottled sandy clays and thick gravel layers and lenses, correlated by Ward (1966, fig. 8) with the Late Pliocene Seaford Formation and the Early Pleistocene Ochre Cove Formation. A stratigraphic column measured by Ward (1966) at Sellicks Trig. is shown in Figure 2. The base of the column, which lies 7.3 m a.s.l., is marked by a 1 m thick unit of boulder conglomerate which was regarded as being equivalent in age to the Pliocene Hallett Cove Sandstone. Above this layer 22 m of red, yellow and grey clays and gravels were correlated with the Seaford Formation from their type section at Ochre Point. Ward (1966) regarded the basal beds of the Seaford Formation as of Lower to Middle Pliocene age because they allegedly interfinger with Hallett Cove Sandstone at Maslin Bay, and the youngest deposits of the Seaford Formation to be no younger than the Late Pliocene. The Seaford Formation is overlain by 16.5 m of Ochre Cove Formation sediments, consisting of red and grey angular gravels and conglomerates with some layers of strongly mottled clays, and interpreted as of Early Pleistocene age (Ward 1966). Sediments of the proposed Late Pleistocene Taringa Formation lie above those of the Ochre Cove Formation, forming a 7 m thick unit of grey clay and gravels, grey fritting sandy clay and a thick gravel layer. The sequence at Sellicks Trig. is capped by 6.7 m of brown to reddish-brown alluvial gravels

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Fig. 1. Coastal landslump at Sellicks Beach. Extent of slump is shown by (a), backwall by (b), bench by (c) and locality of older slumping by (d).

and moderately calcareous clays which Ward (1966) assigned to the Christies Beach Formation of Late Pleistocene age.

Though Ward's (1966) interpretation is generally acceptable, the discovery and identification of the Early Pleistocene marine Burnham Limestone at the base of the sequence requires a re-evaluation of the ages of the oldest formations in particular.

Directly seawards of Sellicks Trig. near a small archway cut in the Miocene Port Willunga Formation, 1-2 m of sandy clays and gravel beds varying in colour from brown, grey-black and light olive green to grey with weak orange mottles rest on the calcreted surface of the Miocene limestones. The sandy clays in places resemble the Seaford Formation. Interbedded with the basal sandy clays are several layers of clasts, dominantly cobble-sized, which may be the boulder conglomerate referred to by Ward (1966). Overlying this is a 1 m thick layer of relatively soft, friable and marly carbonate rock which contains a rich marine fauna. The limestone has been iden-

tified as the Early Pleistocene Burnham Limestone because of its lithology and the presence of the distinctive Early Pleistocene gastropod *Hartungia dennanti chavani* (kindly identified for us by Dr Ludbrook) described from the Point Ellen Formation of Kangaroo Island (Ludbrook 1983) and the Roe Calcarene of the Eucla Basin (Ludbrook 1978). The Burnham Limestone (Firman 1976, Ludbrook 1983) has not previously been reported from this locality, nor has *Hartungia* previously been reported from the Burnham Limestone. Between 0.5 to 2 m above the Burnham Limestone a 10 cm layer of soft, white dolomite rests on grey clays. The sandy clays immediately above the Burnham Limestone appear similar to some of those below it; thus the limestone may represent a marine interval during the deposition of the sediments of the Seaford Formation, which in this locality must be regarded as having an Early Pleistocene age rather than the Mid- to Late Pliocene age preferred by Ward (1966). Moreover, we consider that the Hallett Cove Sandstone at

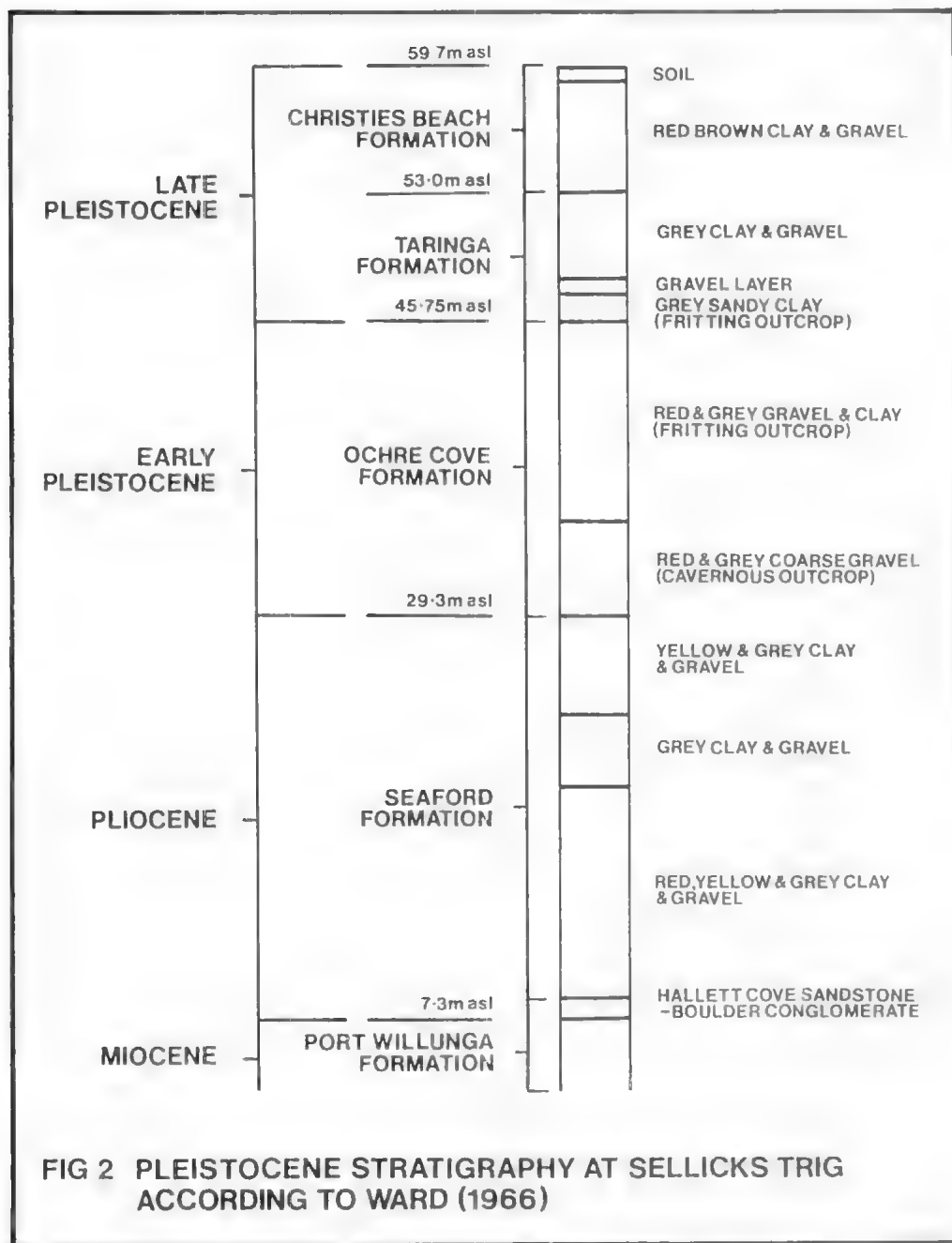


Fig. 2. Pleistocene stratigraphy at Sellicks Trig according to Ward (1966).

Maslin Bay near Tortachilla Trig. does not interfinger with the Seaford Formation as suggested by Ward (1966) but that the Seaford Formation overlies the Hallett Cove Sandstone. We consider the thin (approximately 1 m thick) layer of limestone that occurs within

the Seaford Formation to be the Early Pleistocene Burnham Limestone. Consequently, the Ochre Cove Formation may be younger than the Early Pleistocene age ascribed to it by Ward (1966). An Early Pleistocene age for the Ochre Cove Formation is essential to the

sea level scheme proposed by Ward (1965, 1966) and defended by him (Ward 1967) against the criticisms of Twidale *et al.* (1967), although subsequently Ward (1975) conceded that there are no localities where there is certain proof of coastal stability from which reference sea levels can be calculated. New information presented in this paper demonstrates that the Ochre Cove Formation is not of earliest Pleistocene age, so that a re-evaluation of both the ages of the sediments and the eustatic and climatic history of the area as proposed by Ward (1966) is required.

The precise characteristics of the Seaford and Ochre Cove Formations at this locality are sometimes difficult to determine because of the colluvial mantle of coarse gravels masking the underlying sediments. However, occasional heavy rains in the winter of 1983 tended to strip the colluvial mantle and expose the underlying sediments, especially in several steep-sided gullies through the section.

Ward (1966, p. 43) considered that part of an inaccessible outcrop at Sellicks Trig. might be Ngalinga Clay although he mapped it as part of the Taringa Formation. We believe that this outcrop is, in fact, Ngalinga Clay. The inclusion of clasts within these sediments may have influenced Ward's (1966) decision to map them as Taringa Formation. However, we consider that the location near the base of the Willunga escarpment would lead to the occurrence of clasts within the generally clast-free Ngalinga Clay. No other characteristics of this unit suggest that it is the Taringa Formation, which is typically a grey, calcareous mudflow deposit with a pronounced columnar structure. Conversely the deposits at Sellicks Trig. are olive-green grey in colour with a friable structure that is a distinctive feature of the basal part of the Ngalinga Clay.

A distinctive calcareous breccia containing fragments of purple and green metasiltstones originally derived from the Cambrian and Pre-

cambrian basement rocks forms a capping over sections of the Christies Beach Formation near the modern ground surface.

Morphology of the bench

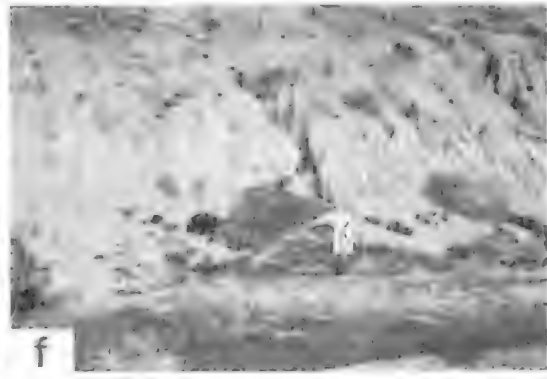
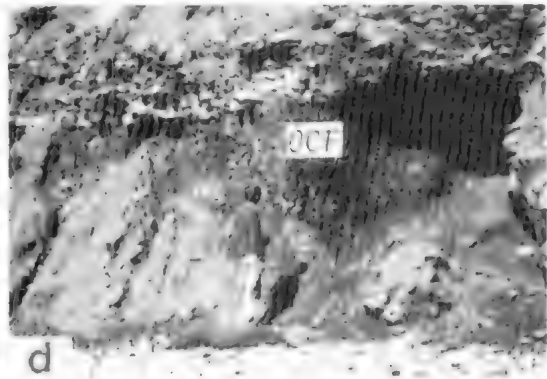
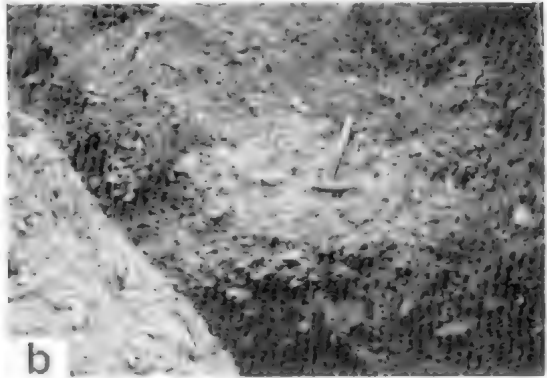
The bench, which lies between 20 m and 26 m amsl, has a maximum central width of 50 m and is backed by an arcuate cliff that rises a further 30 m to the surface of the piedmont plains fronting the Willunga escarpment (Fig. 1). In detail the bench surface is stepped with four major levels being apparent; the highest is at the northern end and each is separated by a drop of one to two metres to the south.

Gullies occur in the lower cliff and they have eroded headward about 20 m into the bench surface, following the bases of steps on the bench. Towards the seaward edge of the bench crenulated and hummocky features rise up to 2 m above the general bench level. Exposures in these micro-forms reveal disordered gravels and clays. Vegetation consisting of grasses and stunted bushes is well established on both the bench and the northern section of the steep backing cliff. Towards the central section of the bench, however, the cliffs are bare indicating that more recent spalling or settling may have occurred here.

Description of the slump

Both the gross and detailed morphology of the slump are consistent with a large section of the cliff having subsided and tilted. The rotational movement is indicated by the disposition of gravel layers exposed in the most northerly gully across the bench. The bedding of the Pleistocene sediments at Sellicks Beach, as a result of their deposition on aggrading alluvial fans at the base of the Willunga escarpment, dips at approximately 5° to the north. On the other hand, the beds in the gully dip at up to 45° to the east demonstrating pronounced dislocation. At this site recent

Fig. 3a: Back-tilted Late Pleistocene Christies Beach Formation sediments (CBF) and an inclusion of Taringa Formation deposits (TF), overlain by seaward dipping recent colluvium (c). View in northern most gully looking south. 3b: Hammer rests on inclusion of mottled Ochre Cove Formation sediments within much disturbed deposits of Christies Beach Formation. 3c: Erosional hollow in Miocene Port Willunga Formation (PWB) limestones through which Pleistocene sediments (P) were funnelled. 3d: Vertically tilted Middle Pleistocene Ochre Cove Formation sediments (OCF) overlain by horizontally disposed Late Pleistocene cobbles and boulders. 3e: Stranded boulder beach (bb) rests on Port Willunga Formation limestone several metres above the modern shore platform. 3f: Small alluvial fan (f) developed on slump surface by gullying of undisturbed sediments exposed in backing cliff. 3g: View of slump surface looking north. Note stepped nature of bench and hummocky rolls of material in left foreground. 3h: Back-tilted Pleistocene sediments related to older phase of slumping near Sellicks Trig.



colluvium with a gentle seaward dip overlies the steeply dipping gravel beds (Fig. 3a). In some other gullies below the bench level the sediments have been totally masticated, with all original bedding having been destroyed. Both the disturbed nature of the sediments and the undulating topography near the seaward margin of the bench can be attributed to seaward flow of material following rotational slumping of the former cliff-top.

Sediments of the Ochre Cove Formation and younger formations, as described above, are exposed in the cliff backing the bench. In exposures below the bench, however, sediments of the youngest formation at this site, the Christies Beach Formation, rest directly on the Miocene limestones of the Port Willunga Formation or on the Early Pleistocene Burnham Limestone. The beds of the Seaford Formation have been totally removed by the slumping and only occasional patches of dislocated Ochre Cove Formation sediments occur near the seaward edge of the slump. Sediments of the Christies Beach Formation have been greatly disturbed with the original bedding having been destroyed. Small isolated inclusions of mottled Ochre Cove Formation sediments up to one metre in diameter occur sporadically within the disrupted Christies Beach Formation (Fig. 3b). In the northernmost gully a two metre diameter slab of a grey calcareous sediment that resembles the Taringa Formation occurs as an inclusion within the sediments of the Christies Beach Formation even though no Taringa Formation appears to be exposed in the cliffs immediately backing the bench. It may have derived from a small, isolated channel fill.

Approximately 300,000 m³ of material has been removed from the cliff face as a result of the slump and the total volume of material involved in the mass movement must have exceeded twice this amount. The volume of material involved was such that a frontal lobe is likely to have flowed across the beach into the sea. The stepped nature of the bench surface, the arcuate and steep backwall, the hummocky nature of the seaward edge of the bench and the flowage of a frontal lobe into the sea together with backward tilting of the sediments is typical of coastal rotational landslumps such as those of Axmouth and Folkstone Warren (Ward 1945), and smaller slumps on the Christchurch Bay coastal cliffs (Barton *et al.* 1983).

Heath (1963) recognised major slump structures in bleached Cretaceous shales near Oodnadatta, several of which are of comparable size to the slump described here. These structures, which occurred on the margins of a duricrust capped plateau were established as slumps on the basis of excessively steep local dips in comparison with the regional disposition of bedding. The occurrence of these slumps along the weathering front was attributed to undercutting of less resistant shales at the cliff base, thereby initiating gravity flows along water saturated joints and partings in the kaolinitic shales.

Possible causes of the slump

Major dislocation of the stratigraphic succession is apparent in the structure we have identified, and because of the disrupted nature of the Christies Beach Formation sediments and the occurrence of inclusions of blocks of material from older formations within it, slumping and saturated flow are the likely mechanisms involved. Sediments underlying the bench have been tilted but are otherwise not disrupted, while at the seaward edge sediments of both the Christies Beach Formation and the Ochre Cove Formation have flowed together in an uncohesive mass. Thorough wetting of the sediments facilitating flowage in a near saturated condition appears to be one prerequisite to explain the evidence observed. This would have required intense and/or prolonged rainfall. An impermeable layer at the base of the structure would have assisted the saturation of the overlying sediments and increased the possibility of mass failure. The Pleistocene sediments at Sellicks Beach are relatively permeable because of the coarse gravel layers. Similarly the underlying limestone of the Port Willunga Formation is also permeable, but the clays incorporating the Burnham Limestone interval may have provided a sufficiently impermeable layer to assist saturation, and the slip appears to have occurred essentially along this layer. In the <2 μ m fraction of these clays, kaolinite and illite are the sub-dominant clay minerals present, whilst smectite, which has expansive characteristics, is the dominant clay mineral and could have acted as a catalyst for the slump.

Several large channels 5 m to 30 m wide form part of the karst surface developed on the upper surface of the Port Willunga Formation and extended to or below beach level

(Fig. 3c). In these hollows the Early Pleistocene Burnham Limestone has been removed, whereas on the intervening higher sections, the marine sediments usually remain. These hollows may have acted like funnels, channeling the slumped sediment seaward in long tongues.

The proximity of the slump to the Willunga Fault suggests the possibility of tectonic triggering; there is evidence of considerable tectonic displacement across the fault zone. Ludbrook (1983) points out that the Burnham Limestone occurs as thin discrete remnants along the coast south of Adelaide from Kingston Park to Port Willunga, decreasing in elevation from 30 m at Hallett Cove to 20 m at Maslin Bay. The distribution of the Burnham Limestone can now be extended to Sellicks Beach where it lies at approximately 8 m amsl thereby corroborating the southward dip of the formation. The time equivalent Point Ellen Formation occurs at 50 m amsl at Cape Jervis. Variations in elevation between this site and the lower occurrences on Kangaroo Island were interpreted by Ludbrook (1983) to be due to gentle warping of less than 1°. However, the proximity of the Burnham Limestone at Sellicks Beach to the marked disturbances of Miocene and Middle Pleistocene sediments suggests considerable tectonic dislocation of the Early Pleistocene deposits across the site of the Willunga Fault at least.

Campana & Wilson (1953) illustrate Early Pleistocene gravels in a clearcut tectonic contact with Cambrian rocks in the Mt Terrible Gully 500 m south of Sellicks Trig. The gravels are tilted and are overlain by younger horizontal beds (Campana & Wilson 1953, fig. 2). These authors also figure tilted upper Pleistocene gravels near the mouth of Mt Terrible Gully (Plate V, fig. 2) to illustrate post-Pleistocene tectonic disturbances. We were not able to locate this last-mentioned site, but south of the mouth of Mt Terrible Gully where Miocene limestones of the Port Willunga Formation have been tilted steeply by tectonic movements. Ochre Cove sediments, which we regard to be of Middle Pleistocene age, have been tilted into a vertical position (Fig. 3d). These beds and the adjoining Miocene limestones have been truncated by the sea when the shoreline stood about 4 m higher than present, during which time a boulder beach (Fig. 3e) was produced and incorporated shell fragments and occasional intact molluscs that

have been superficially abraded. Behind the boulders are back-beach or dune sands containing calcareous rhizomorphs. This former shoreline is horizontally disposed, and extends along the coastline for hundreds of metres, although in places there are erosional breaks. A radiocarbon date on the shells incorporated within the boulder beach yielded an age in excess of 30 000 years B.P. (GaK-6095). Thus the beach is probably related to the Late Pleistocene Glanville Formation deposited during the last interglacial. This shoreline has not been obviously tilted.

The above evidence suggests that tectonic dislocation of Miocene, Early Pleistocene and probable Middle Pleistocene sediments has occurred. Moreover, seismic activity has continued throughout the St Vincent Basin to modern times (Sutton & White 1968, Steel 1962), so that there has been ample potential for seismic triggering of saturated coastal sediments.

Many coastal cliffs fail due to undercutting of the base of the cliff by marine erosion (see, for example, Ward 1945, Rozier & Reeves 1979). At present the limestone of the Port Willunga Formation provides a buttress to erosion of the softer Pleistocene sediments and would have done so in the past, which might suggest that marine erosion is less important than other factors in generating the slump. However, there is considerable evidence for active marine erosion along this section of coastline (Howchin 1923, p. 313, Bourman 1976). The possibility of a world-wide 1 m higher stand of the sea during the Holocene has been suggested (Chappell *et al.* 1982, Chappell *et al.* 1983) and there is some evidence for a higher shoreline along St Vincent Gulf and Spencer Gulf during the Holocene (Ward 1966, Bourman 1972, Gastin *et al.* 1981). However, Belperio *et al.* (1983) maintain that the evidence is equivocal. If this postulated higher sea level did occur, although its occurrence is not vital to the initiation of the slump, then the processes of marine erosion would have intensified. The higher shoreline of probable Late Pleistocene age that truncates the tilted Ochre Cove Formation sediments is not relevant to this discussion because it predates the slumping by many thousands of years.

It may seem anomalous that the slump actually occurs behind the buttress of Port Willunga Formation limestone. However, the

presence of the limestone would have allowed the development of a steeper cliff face here than elsewhere, whereas the slopes on unconsolidated sediments would have re-adjusted rapidly to basal steepening by marine erosion. Moreover, where the Port Willunga Formation crops out the clay-rich layer including the Burnham Limestone is also exposed above sea level to provide a slip-plane layer.

The present steepness of the coastal cliffs backing Sellicks Beach is a consequence of marine erosion. Moreover, as active rotational slipping is essentially confined to slopes undergoing basal erosion (Brunsden & Jones 1976, Goudie 1981, p. 158), the role of marine erosion in developing the rotational slump at Sellicks Beach is probably far more significant than other factors. Immediately south of the slump an extensive shore platform occurs in the intertidal zone, which has the effect of refracting waves to concentrate their attack on the cliff fronting the site of the slump; this factor may help to explain the precise location of the slump.

Basal steepening by wave attack and saturation favoured by the presence of an impermeable layer probably established the ideal circumstances for rotational slumping to occur, while seismic activity or even vibrations generated by storm waves may have acted as the trigger for the mass failure.

Possible age of the slumping

No indications of the slump having taken place since European settlement have been found. Consequently the failure occurred more than 150 years ago. Debris on the beach and in St Vincent Gulf would be expected to result from outward flowing of the toe of the slump. However, no remnants of the flow remain seaward of the cliff. Arber (1973) described a land slump at Dowlands, Devon, England, which produced a 1200 m long reef in the sea, but which survived only a few months. Thus lack of debris on the beach may not be crucial in assessing the age of the slumping. Similarly, the vegetation on the bench could have become established in a relatively short period especially as much of it is exotic. Gullies which have been eroded into the bench down to beach level and into the backing cliff have involved the removal of considerable amounts of sediment and the construction of a small alluvial fan on the bench surface (Fig. 3f). Erosion of the bench and the

backing cliff suggests that more time has lapsed since the slumping occurred than indicated by either the vegetation present or the lack of flow debris on the beach.

The preservation of detailed hummocky topography on the seaward edge of the bench surface (Fig. 3g) is suggestive of a relatively recent age for the slumping. The bench surface topography appears to be more subdued in the northern section of the slump, which may suggest that the southerly section is of a more recent age. However, there is no corroboratory evidence to confirm that this is the case. An S-shaped feature occurs at the base of the cliff, immediately landward of the central gully that dissects the bench, on the 1949 aerial photograph (Fig. 1). This structure is now obscured by colluvium, derived from the backing cliff. This process of colluviation on the bench surface continues to the present.

The local stratigraphy is most useful in determining the age of the earth movement. Sediments of the Christies Beach Formation are clearly disrupted by the slumping as is the youngest sediment in the backing cliffs, the calcareous breccia that overlies the Christies Beach Formation. Blocks of the calcareous breccia occur on the seaward margin of the bench. Slumping therefore postdates the Late Pleistocene. A lens of dark sandy clay which resembles the Waldeila Formation that occurs in nearby Sellicks Creek (Ward 1966) is present in a small gully below the bench suggesting that slumping occurred after or during the period of time when the Waldeila Formation was being deposited. Shells incorporated within the Waldeila Formation in the lower Onkaparinga River Valley have been dated at 4580 ± 160 B.P. (Bourman 1979) (GaK-6094). Hence a Late Holocene age is postulated for the rotational slump. The colluvium which overlies the back-tilted Christies Beach Formation sediments at the northern end of the slump supports a Late Holocene age for the slump and may offer opportunities for colluviation dating, a technique applied successfully on an abandoned London Clay sea cliff at Hadleigh in Essex by Hutchinson & Gostelow (1976).

Implications

The identification of a large land slump at Sellicks Beach indicates potential instability along the cliff line. Not only is there evidence of a large Holocene coastal slump north of Sellicks Trig. but immediately south of the



Fig. 4. View of sediments involved in older slump which occurred through a depression in the Port Willunga Formation (PWB). Upthrusting of Burnham Limestone (BL), dolomite layer (d) and other light-coloured sediments (1) is especially notable on right side of photograph. Minor bench level about half way up cliff at (b) represents remnant of a once more extensive slump surface.

trig, older slumping has also occurred. There is no clear topographic expression of this earlier phase of slumping, but sediments have been back-tilted and disturbed by mass movement (Fig. 3h). This older slump appears to have been funnelled through a broad depression in the underlying Port Willunga Formation. The originally horizontal Burnham Limestone and the thin dolomitic layer above it have been disrupted and thrust to higher levels by rotational back-slumping (Fig. 4). Both of the major slumps discussed above occurred behind buttresses of Miocene limestone, so that a natural buttress to erosion does not ensure protection from cliff failure.

Smaller slumps have also occurred on the northern side of Mt Terrible Gully in similar sediments where fluvial undercutting has steepened slopes. This suggests that further slumps could be expected along the coastal cliffs at Sellicks Beach. During the winter of 1983 a small scale slump occurred at the head of the gully near Sellicks Trig. Thus slumping appears to be an important process in both the headward erosion of the gullies in particular and in the retreat of the coastal cliffs generally.

Small scale slumps pose little immediate threat to the houses built on the cliff top, but a major slump of the size of the one reported here would place a number of dwellings at

risk. Indications of potential failure might be the development of tension cracks or structural weaknesses in buildings. Investigations along these lines could be used in developing a coastal management plan for the area, and could be extended to other similar areas such as at Kingston Park, where houses have been built on steep cliffs underlain by Pleistocene sediments close to a fault zone, and at Witton Bluff where coastal erosion is very pronounced in Cainozoic sediments.

Man's effect on the potential for further earth movements also requires investigation. At Sellicks Beach a pathway has been built down to beach level from the cliff top at the northern end of the land slump. Large gutters are being eroded along the path and these may encourage infiltration of water into the cliffs and create the potential for further movement. Rates of infiltration may also be altered by runoff from roads, by heavy watering of domestic gardens and by extensive use of septic waste disposal systems. Any of these factors which increase the infiltration of water into the sediments has the potential to increase cliff instability.

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THE ENIGMA OF THE TINDAL PLAIN, NORTHERN TERRITORY

BY C. R. TWIDALE

Summary

The Tindal Plain, near Katherine, N.T., is a karst plain notable for its pinnacles, for prongs developed beneath the natural land surface, and for its survival. The Plain is of exhausted type, and is the surface upon which the Lower Cretaceous Mullaman beds were deposited. It is suggested that the bedrock has survived marine transgression because the sea was essentially saturated with lime, and has resisted subsequent epigene attack because the bare bedrock is essentially dry, though doline and cave development are active where there is a (moist) soil cover.

THE ENIGMA OF THE TINDAL PLAIN, NORTHERN TERRITORY

by C. R. TWIDALE*

Summary

TWIDALE, C. R. (1984) The enigma of the Tindal Plain, Northern Territory. *Trans. R. Soc. S. Aust.* **108**(2), 95-103, 12 June, 1984.

The Tindal Plain, near Katherine, N.T., is a karst plain notable for its pinnacles, for prongs developed beneath the natural land surface, and for its survival. The Plain is of exhumed type, and is the surface upon which the Lower Cretaceous Mullaman beds were deposited. It is suggested that the bedrock has survived marine transgression because the sea was essentially saturated with lime, and has resisted subsequent epigene attack because the bare bedrock is essentially dry, though doline and cave development are active where there is a (moist) soil cover.

KEY WORDS: Karst, exhumed surface, dolines, Tindal Plain, Northern Territory.

Introduction

Between Venn and Katherine (Fig. 1) the Stuart Highway, and the now disused North Australian Railway, both pass over a virtually flat limestone surface, underlain by and developed upon the Tindall Limestone, of Middle Cambrian age (Randal 1963) and here called the Tindal Plain after the air base centrally located upon it. (The discrepancy in spelling is due to error by the geological nomenclature authority.) This karst plain occupies an area of roughly 45 km² extending several km on either side of the S.E.-N.W. transport corridor.

It is a broadly rolling feature situated between 140 m and 200 m above sea level. Though there is a relief amplitude of some 60 m within the area occupied by the plain, slopes are gentle save in the vicinity of the few widely-spaced incised river channels, some of which drain eastwards to the Gulf of Carpentaria and others westwards to the Joseph Bonaparte Gulf, and around the quite numerous but areally minor low hills that stand above the level of the plain. Many of these residuals can be regarded as properly belonging to other, adjacent physiographic regions, but they are of particular interest in that they provide vital evidence concerning the essential character of the Tindal Plain. There is an anomaly in that though all earlier writers, whether considering the plain in general terms (Wright 1963, Randal 1963) or as a karst form (Jennings & Sweeting 1963), regarded it as a youthful feature, the field evidence strongly suggests that it is an ancient feature of complex derivation, and in some respects difficult to explain. The limestone plain crossed by the Stuart Highway appears to be at least 135 Ma old, and the question arises as to how a feature eroded in such a weak material as limestone has so successfully survived attack by weathering and erosion. This is the enigma of the Tindal Plain.

Background

The Tindal Plain is located within the Daly Basin, a broad, shallow intracratonic structural basin underlain by folded Proterozoic strata and associated igneous emplacements, and occupied by a suite of Cambrian rocks that includes the Antrim Plateau Volcanics and various limestones prominent

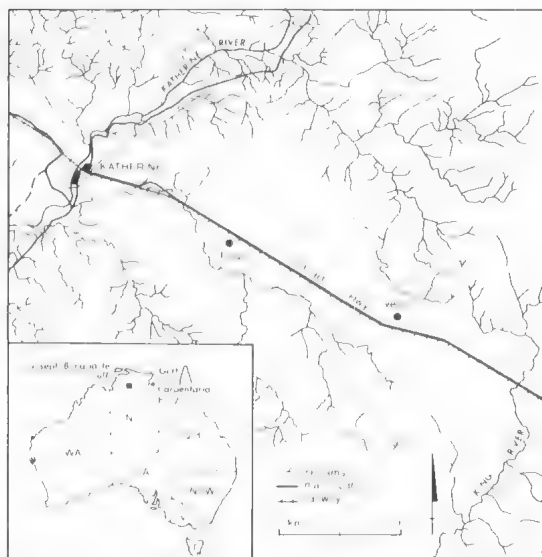


Fig. 1. Locality of Tindal Plain in Northern Territory, Australia.

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amongst which are the Montejinni, Oolloo and Tindall formations, and by the Lower Cretaceous Mullaman beds.¹ The basin structure predates Cretaceous sedimentation and has suffered recurrent reactivation, the Lower Cretaceous quartzitic sequence, for instance, appearing from beneath the succeeding beds on the divide between the Daly Basin and the Wiso Basin to the south.

The Tindall Limestone is a massive crystalline rock with dolomite bands and lenses and thin beds or attenuated lenses of chert that are early diagenetic features. In the Tindall area the limestone is well bedded and jointed and essentially flat-lying, but the fractures are widely spaced so that outcrops are dominated by large angular blocks. The limestone is inherently white in color, but where exposed in the subsurface typically appears to be of a creamy hue, this impression being due partly to a skin of calcite and partly to the contrasted red colour of the adjacent soil. Where exposed to the air, however, the limestone is consistently dark grey or black, this colour being due to an algal encrustation that forms a thin surficial patina. Soot from the periodic burnings to which this district is subject may also have contributed to the surface discoloration. The Tindall Limestone retains these characteristics on both sides of the Stuart Highway, but the Oolloo Limestone exposed in the Fitzmah Quarry some fifty km southwest of Katherine is finely bedded and grey in colour, and, unlike the Tindall, has no pinnacles or other residuals associated with it. Again, the karst plain developed on the well bedded, almost flaggy Montejinni Limestone around Top Springs, is featureless and lacks the blocky residuals characteristic of the Tindall Limestone outcrops.

The Cambrian rocks are unconformably overlain by the Mullaman beds which consist of a basal quartzite exposed on structural highs. According to Skwarko (1966) the basal member of the Mullaman beds, the Lees Sandstone, is a massive, poorly sorted saccharoidal quartz sandstone. The lower members are characterised by cross-bedding and plant remains suggestive of a lacustrine environment, though the higher part of the sequence is regarded as marine. An overlying argillaceous member is well-bedded and jointed and consists of siltstone and mudstone, but is com-

monly weathered to a lateritic profile consisting of a silty A-horizon, a pisolitic ferruginous B-horizon and a C-horizon that comprises mottled and pallid porcellanic material. Where exposed, the sandstone too is silicified and slightly ferruginised. In places a pisolitic ferruginous layer is preserved either as a surface cover or as an infilling to minor pipes and basins developed on the quartzite.

Lateritisation took place in this region in the later Cretaceous and Early and Middle Cainozoic, ceasing in the Miocene, for various later Cainozoic sediments and lavas remain unaffected by lateritic weathering (Stewart 1954, Hays 1967, Twidale 1956, 1983). Judging from the conditions in which lateritic soils are forming at present, the climate during this extended period must basically have been warm and humid (Prescott & Pendleton 1952, Sivarajasingham *et al.* 1960, Maignien 1966) a conclusion confirmed by palaeobotanical investigations (see e.g. Kemp 1978). The present climate is warm and sub-humid, Katherine for instance averaging 966 mm of rain per annum, 95% of it falling in the summer seven months October-April, but laterite is not evidently forming at present, and though contrary views are expressed from time to time, it is generally agreed that the laterite of northern Australia is a relic feature.

Lateritisation ceased sometime during the Miocene, partly as a result of regional warping that caused the rivers that had reduced the land surface to one of low relief to be rejuvenated and resume valley incision, partly as a consequence of major world wide climatic changes which both directly affected the environment and also, through the concomitant lowerings of sea level, added to the tendency of exorctic rivers such as those that drain the Daly Basin to incise their beds. According to Wright (1963) these streams exploited variations in the laterite profiles to produce several plains and benches, and *in toto* a stepped relief. The master surface capped by laterite and named the Bradshaw Surface is represented by various scattered but prominent mesa and plateau remnants, with the Maranboy and Tipperary surfaces at lower levels. Hay (1967) mentions a sub-Cretaceous exhumed surface that is lateritised in the area west of Mataranka, but does not discuss the Tindall Plain, which is not lateritised and which lies northwest of Mataranka.

¹ Mullaman beds, lower case "b", is the official stratigraphic term.

In the course of a brief reconnaissance, Jennings & Sweeting (1963) noted the bare karst developments and also some recently formed dolines south of Katherine. They related the soil cover to the present climatic conditions and accepted Litchfield's (1952) interpretation of the sandstone that forms scattered outcrops on the plain as part of the same stratigraphic formation as the limestone that underlies it, a view which, in turn, reflected the prevailing geological opinion of the time. Thus they were led to consider the karst plain as a youthful feature, despite the presence of limestone pinnacles which are prominently developed on the Plain, and which are generally considered as representative of mature karst landscapes; though the term "youthful" may have been used in the general sense of "little-dissected", which the Tindal Plain certainly is.

Evidence

The Plain Proper: Two types of surface can be distinguished within the Plain. First, there are the many areas of exposed limestone. They have a well developed system of N-S and E-W trending joints disposed essentially normal to one another (Fig. 2) and with the prominent horizontal bedding, forming an orthogonal set that subdivides the limestone into cubic and quadrangular blocks. In detail, these rock outcrops are rough due to the development of innumerable clints, tables and blocks separated by wide grikes or widened and weathered vertical joint planes (Fig. 3). The limestone blocks are typically fluted, though the furrows are vertically zoned, the lower parts of the blocks being not only smoother but also steeper and paler in colour, suggesting a recent lowering of the soil surface between the blocks of some 20–30 cm. In places the presumed former soil level is marked by a rim of calcite. Also the thin interbeds and attenuated lenses of chert stand out as minor ledges and rims. There are also many small, shallow dolines which lead down to quite extensive cave systems such as that at Cutta Cutta. These vertical shafts provide good exposures of the honeycombed nature of the rock immediately beneath the blocky outcrops (Fig. 4).

The second type of surface (Fig. 2a) is underlain by a greater or lesser thickness of red or light brown soil. The presence of quarries in this soil immediately adjacent to rock outcrops (as, for instance, near the

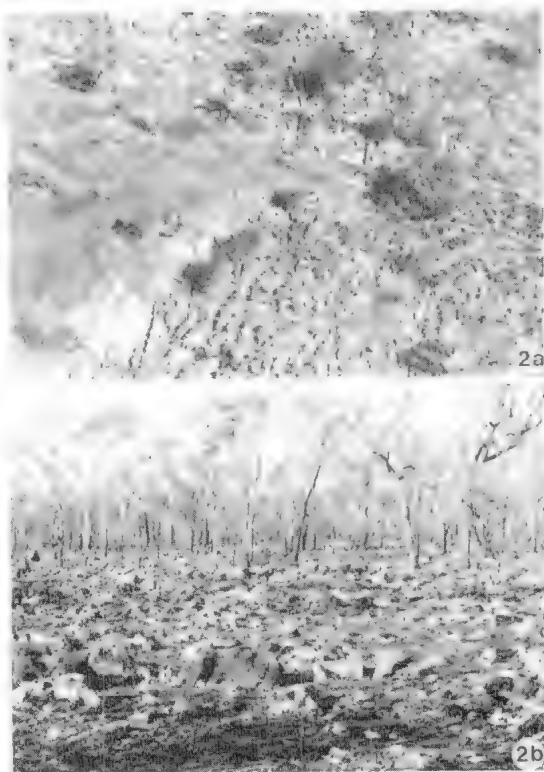


Fig. 2. (a) Rock and soil plains, Tindal area, N.T. (b) Detail of karst plain, near Tindal.

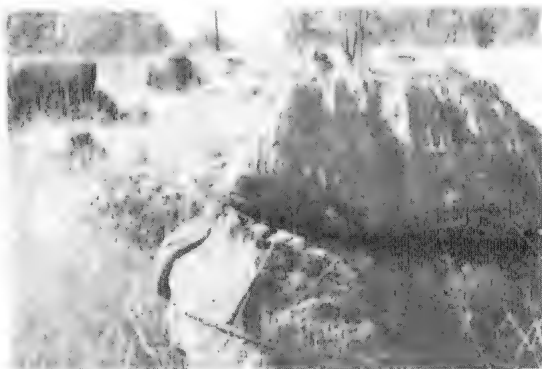


Fig. 3. Limestone tables with fluted sidewalls, and, near hammer head, Cretaceous sandstone preserved in bedding plane.

southern extremity of the Tindal runway) suggests that the contacts between fresh rock and the soil are steep. According to Litchfield (1952) the soils consist predominantly of fine sand, though with an increasing proportion of silt and clay with depth. They are only moderately alkaline (pH 6.2–7.2) throughout, and their depth varies between a few cm to a least

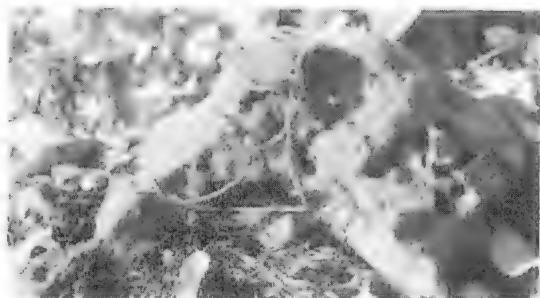


Fig. 4. Honeycombed limestone exposed near mouth of doline near Tindal.

9 metres. These soils are unlikely to have been derived entirely from the weathering of the Tindall Limestone, and are more likely a mixture of ancient red earth and basal Mullaman sandstone.

Dolines developed in the late 'seventies near the old Venn airstrip provide excellent exposures of the soil-rock contact. A group of six dolines is developed in a broad, shallow topographic depression between the Stuart Highway and the old North Australia Railway embankment about 3.5 km northwest of the Cutta Cutta Park turnoff (Fig. 5). Two of



Fig. 5. Dolines formed within the last decade near Venn, N.T.

the dolines are of quite large diameter, the others small. The largest doline has a diameter of about 13.5 m and though it can fairly be described as circular in plan it is in detail irregular and scalloped in outline. It is about 9 m deep. The others are similar in depth but are of lesser diameter. The dolines are interesting not only because of their recent development and their having formed in an ill-drained depression that is partly of anthropogenic origin, but also because the form of

the contact between the red soil and the cream-coloured limestone is well exposed. After the development of the dolines, soil from the adjacent areas was washed into the depressions, exposing the irregular basined bedrock surface (Fig. 6). The limestone basins are separated by sharp ridges or *arêtes* that form a polygonal pattern in plan. The area of such basins and *arêtes* extends beyond the confines of the topographic depression and to the west of the railway embankment, suggesting that the fine soil has been washed through the matrix of the ballast that forms the embankment and into the dolines.



Fig. 6. Basined limestone surface exposed as result of original soil cover being washed into recently formed dolines near Venn.

Isolated blocks (*Karrenblocke*, *Karrensteine*) can be seen in various stages of exposure from the natural soil cover, and the naturally buried rock surfaces display a differential etching of the calcite crystals to produce a rough surface comparable to the pitting described from granitic terrains (Twidale & Bourne 1976) and seen also developed on limestone, though in the zone of seasonally Galong in central N.S.W. The presence of corestones set in a matrix of red soil shows beyond doubt that some, at least, of the free boulders exposed at the surface owe their origin to differential subsurface moisture attack.

The upper surface of the limestone mass is highly irregular with tall prongs or fingers (one of them with flared sidewalls) up to 3 m high and separated by deep soil-filled pipes comparable to the gulls, *puits naturels* or *orgues géologiques* of the European chalk country (Fig. 7).

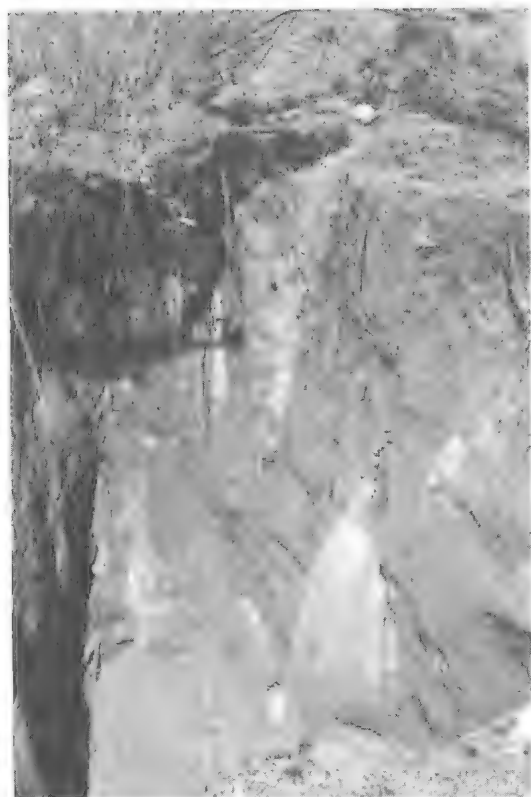


Fig. 7. Sidewall of recent doline near Venn, with limestone prongs and pipes filled with red soil between.

A similar bedrock morphology, with limestone prongs, about 6 m high, projecting into the soil cover was noted in 1959 by M. M. Sweeting and J. N. Jennings in a freshly developed doline adjacent to, and indeed encroaching upon, the Stuart Highway, some 27 km southeast of Katherine (Jennings, *pers. comm.*, December 1983). It is interesting to speculate that the small pinnacles that are prominent in parts of the area (see below and Fig. 8) may be, in part, such prongs that have been subjected to sculpture and superficial modification after exposure.

About 1 km to the southeast (between the main doline site and the Cutta Cutta turnoff), but also in a broad natural topographic depression and located between the railway embankment and the road, there were (August, 1983) two shallow (less than 1 m) depressions in the red soil plain. They are incipient dolines, and are defined by dirt scarps; associated with them are a few arêtes of limestone, indicating that even at this early stage of development soil has already been

washed into the depression from the surrounding areas.



Fig. 8. Pinnacles with fluted sidewalls, northwest of Katherine, N.T.

Residual Hills: The plain is broken by residual hills of several types. Though quite numerous, their total area is small; nevertheless they provide essential evidence as to the age and character of the Tindal Plain. Small groups of limestone boulders together form low rises that might be termed low blocky nubbins. The limestone blocks, tables, pinnacles (or minor towers) and perched blocks are black and intricately fluted (Fig. 8). Some honeycomb weathering is present. The open bedding planes are prominent, and rock basins are also developed. In some areas pinnacles up to 4 m tall dominate the groups, as for instance on the western side of the Stuart Highway, some 13 km northwest of Katherine.

Also present are several low hills, standing up to 7–8 m above the plain level, that are blocky, but nevertheless plateau-like. Again, every exposed surface is black and fluted, and bedding planes are prominent. In several areas, and especially toward the margins of the Plain, there are mesas of lateritised Lees Sandstone that are preserved by virtue of the ferruginous capping, or lower mesas of porcelanite, some of which lack any caprock.

Perhaps of greatest interest, however, are the many residuals, high and low, that consist of Lees Sandstone boulders, most of them *in situ*. In some instances there is a scatter of blocks and boulders, elsewhere merely a "skin" of sandstone on the underlying limestone (as, for instance, near the display centre in the Cutta Cutta Park), but at some sites there are blocky sandstone hills standing up to 10 m above the plain. Weathering rinds are well

developed on some of the boulders. Other features include mushroom or hoodoo rocks, polygonal cracking, flared boulders and slopes, grooves or *Rille*, and several more or less bizarre conformations. In these areas the soil is locally and superficially sandy due to wash from the residuals, but the most significant feature of these sandstone hills, a characteristic they share with the lateritised and porcellanic remnants, is that the unconformity between the Cretaceous rocks and the underlying Cambrian limestones is consistently contiguous with the level of the adjacent plain.

exhumed type of pre-Cretaceous age is surely the only explanation that accommodates the observed data. It cannot be argued that the plain is a Late Cainozoic, much less a recent feature. What are construed as basal Mullaman beds are intimately associated with the karst forms, major and minor. It is concluded that the Plain and many of the karstic forms associated with it were already in existence when the Mullaman beds were laid down.

The karst forms cannot be attributed to differential weathering beneath a cover of Mullaman beds, for the basal Mullaman is

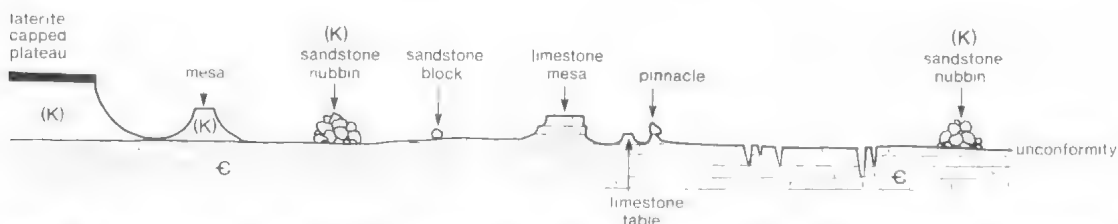


Fig. 9. Diagrammatic section through Tindal Plain, showing relationship between laterite, Mullaman beds and Tindall Limestone.

Nature of the Tindal Plain

There are so many residuals in which the unconformity is continuous with plain level (Fig. 9) that it cannot be fortuitous. To argue that the limestone between the surviving remnants has everywhere been reduced to the level of the unconformity is asking overmuch of coincidence. The Tindal Plain is essentially the surface on which the Lower Cretaceous Lees Sandstone was deposited. It is therefore an exhumed plain of pre-Cretaceous age. This interpretation is confirmed by the common occurrence of quartzite boulders, some of them with honeycomb weathering, both on the rocky limestone plain and scattered amongst the limestone blocks of the plain and of low rises. The presence of small blocks of Lees Sandstone (as, for instance, at an outcrop about 4.5 km northwest of the Cutta Cutta turnoff) in widened bedding planes, on joint planes and within the flutings and tubes that comprise honeycomb weathering lends support to this suggestion. Also, and more commonly, a skin of red gritty sandstone with a thin skin of silica, which is interpreted as a mixture of basal Lees Sandstone and the red soil and developed on the Tindall Limestone in pre-Cretaceous times and incorporated in the basal Mullaman beds (Fig. 3), is preserved on the limestone blocks. That the Tindal Plain is of

essentially unaltered and rests on fresh Tindall Limestone. The basal Mullaman beds are slightly more ferruginous than the rest of the section (and this may be associated with the later lateritisation) but nowhere is there a red soil preserved between fresh sandstone and fresh limestone. For the same reason, the karst plain and associated low limestone hills cannot be interpreted as a simple etch surface due to stripping of an earlier developed regolith, for if such were the case a regolith would surely be preserved between sandstone and limestone? On the other hand there is clear evidence of active dissolution beneath the land surface, beneath the soil cover; contemporary solution has at least maintained the karstic nature of the rocky plains.

Sequence of Events

The most likely sequence of events to which the present landscape may reasonably be attributed involves the Cambrian strata being weathered and reduced to a surface of low relief by the Late Jurassic, prior to the deposition of the Early Cretaceous Mullaman beds. As mentioned previously, these earliest Cretaceous strata are supposed by Skwarko (1966) to have been laid down in shallow lakes, and, if so, it may be that wave action stripped the regolith veneer and incorporated

it into the newly deposited basal sediments. Certainly, where wave action is known to have eroded a regolith (as, for instance, on north-western Eyre Peninsula during the Late Cainozoic (Twidale *et al.*, 1977)) pockets of soil have been preserved beneath the incoming rock cover, and these may include the red soils exposed in the Venn dolines, and elsewhere, despite Litchfield's (1952) assertion that the red soils are in equilibrium with the present environment. The present conditions may not be very different from those that obtained 130-140 Ma ago, and the regolith could be a polygenetic feature that has altered in response to changing environment. What is certain is that stream rejuvenation during the Late Cainozoic has caused the stripping of most of the Cretaceous cover, resulting in the re-exposure of the unconformity between the Mesozoic and Palaeozoic beds. The Tindal Plain, and the associated limestone pinnacles and low plateaux, including several of the minor karst features, are exhumed landforms of pre-Cretaceous age.

Preservation

Apart from its antiquity and complex origin, the preservation of the Tindal Plain presents several difficulties. The Mullaman beds that formerly blanketed the region were subjected to deep, intense and long-continued weathering during the Late Cretaceous and through much of the earlier Cainozoic. This weathering resulted in widespread lateritisation wherever the argillaceous sequences were affected. The sandstone was superficially silicified and ferruginised, with concomitant piping and basin development indicative of silica solution. In these conditions it is difficult to understand how the underlying limestone was not altered to such an extent that all original structure was lost. The limestone is certainly well bedded and jointed, and presumably allowed free passage of the meteoric or vadose waters infiltrating into the subsurface.

There is some suggestion that a silicified impermeable horizon evolved within the main laterite profile (Wright 19663) but it is unlikely to have been completely watertight and, indeed, the depth of weathering beneath this horizon within the Mullaman beds argues against such an explanation. Likewise, the porcellanite that is developed on the argillaceous Mullaman beds is silicified, but is too well fractured to be impervious. The basal red beds of the Mullaman, those that are found

plastered on joint faces, etc., are silicified, but there is no evidence that the silicified material is any more than a patina: permeable Lees Sandstone occurs within widened fractures, and this would not prevent the passage of groundwaters.

It may be suggested that the unconformity and the limestone were affected by stagnant saturated groundwaters within a closed system, but, in view of the known perviousness of the Palaeozoic basin sediments and of the Proterozoic basement rocks, this is unlikely. Similarly, any argument that the water table was deep below the unconformity and that groundwaters merely passed through the relevant zones does not bear examination, for it is precisely such throughflow that is conducive to karst development, especially vertical shafts. Also, the development of a lateritic profile on the Mullaman beds surely argues a fluctuating water table well above the unconformity, and the latter located within the zone of permanent saturation. It can be argued that the groundwaters, moving laterally through the system, were of low pH, but this is unlikely in view of their provenance and the evidence of silica solution at the time of lateritisation.

What appears at first sight to be a comparable situation obtains in the lower Mt Arden Valley, in the southern Flinders Ranges, S.A. There, considerable elements of a planate surface cut in Cambrian limestone are preserved as a high plain, now dissected, but with scattered remnants of a cross-bedded conglomerate and sandstone persisting in low, blocky outcrops. The arenaceous strata which have in detail been sculptured by alkaline soil moisture, producing rocks basins, minor flared slopes, etc. were laid down in early Tertiary (Eocene) times in a lake that occupied the northern Willochra Basin (Twidale 1966, 1980). Again, the question arises as to how the limestone survived solution. No pre-Tertiary regolith is preserved at the unconformity and the limestone surface, though weathered to produce minor karst features (fingerprints, minor *Karren*, basins), has not so far yielded any dolines or cave systems. But the Cambrian strata are folded and the fractures in the synclinal structure are arguably so tight as not readily to permit the passage of water. No such tentative explanation, can, however, be applied to the Tindal

region, where the limestone is flat-lying with open joints and bedding planes.

The problem of the preservation of the Tindal karst can be eased, though not resolved, if a basic assumption made by an earlier worker is rejected. The greater part of the present karst, including the differential compartmental weathering, was developed by the end of the Jurassic. The old landscape was then buried by the Mullaman beds, with regolith material being stripped and redistributed by wave action. Skwarko (1966) suggested that the earliest Cretaceous beds were deposited in lakes, largely on the basis of the contained plant (fern) remains. But this interpretation is open to question. The Lees Sandstone is so widespread that the series of discrete lakes envisaged must have been of enormous extent (cf. Twidale & Milnes 1983 with respect to Miocene lake basin deposits in central Australia). Also the sub-Cretaceous surface is consistently of low relief and the question arises as to what rivers carried the sands and spread them over the landscape? There is no large scale cross-bedding and rapid step-up of beds, such as is commonly found in fluvial or lacustrine sandstones. It is much more in keeping with the distribution and character of the Lees Sandstone to suggest that it is marine and associated with an epicontinental sea. The plant remains could have derived from islands, or simply have been washed into such a sea. In such conditions, leaving aside the associated relatively narrow coastal zones, where various types of erosion would likely have been active, the limestone floor may have been only superficially affected, for the sea water, if comparable with that of today, would have been saturated with lime and therefore incapable of carbonate dissolution. Even so, it is difficult to understand why marine erosion (physical, chemical, biotic) did not eliminate such comparatively fragile features as the pinnacles. It may be that the small limestone plateaux and hills stood as islands in a shallow sea and survived in a low energy environment.

Finally, why has the limestone surface not been weathered to a far greater extent than it has since exposure in Late Cainozoic times? After all, the region receives a considerable rainfall, albeit on a markedly seasonal basis, and the area is covered by a woodland that produces a considerable litter which decays to produce various organic acids (see e.g.

Hingston 1962). Rates of limestone solution vary considerably (see e.g. Sweeting 1973 pp. 41–42) but are almost everywhere, and certainly under the prevailing conditions, enough to have caused a deep soil to develop throughout the plain under consideration. Undoubtedly there has been some recent solution and, indeed, recent doline development, but large areas of the plain have been preserved. Moreover there is evidence that the rocky nature of the plain is being enhanced as soil is washed away, possibly as a result of anthropogenically introduced environmental imbalance. Even in areas of well-bedded and jointed limestone, such as that exposed in the Fitzmah Quarry, little subsurface weathering is in evidence.

One possible explanation is that, as has been suggested by several authors (de Saussure 1796 in general terms, Monroe 1964 p. 108, Panos 1964 p. 12, Panos & Stelcl 1968, Gams 1979, 1981 with respect to limestone, Barton 1916, Bain 1923 with regard to granitic rocks), rocks that are dry are weathered only very slowly, whereas those that are wet, and especially those that are covered by a moisture-retaining regolith, are altered very rapidly. And the Tindal Plain may well be effectively arid. There is a long dry season; in the summer wet, water rapidly disappears beneath the surface into the cavernous riddled rocks; burning ensures that there is little in the way of ground cover to retain moisture; and human interference added to the natural systems has recently caused accelerated soil erosion, causing the moisture retaining soil to be stripped away to a depth of 20–30 cm and leaving the bare rock that much in relief. Moreover, there is a reinforcement effect (Twidale *et al.* 1974), for the more an outcrop stands in relief, the greater is the tendency for water to run from it to the adjacent plains.

Beneath the soil-covered plains, on the other hand, the exposures revealed in the Venn dolines suggests that solution not only has been, but probably still is, active and has produced a differentiated relief at the weathering front. Thus Monroe (1964 p. 108) had good reason to state that "The solution of limestone is most active under soil cover and almost ceases when soil is removed".

Conclusion

The Tindal Plain, which heretofore has been accepted, when it has received any attention at all, as a simple, youthful landform, is in

reality a feature of considerable antiquity and complexity, the origin and persistence of which still pose considerable problems.

Acknowledgments

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A REDESCRIPTION OF THE GENUS TASMANOCOENIS LESTAGE (EPHEMEROPTERA: CAENIDAE) FROM AUSTRALIA

BY PHILLIP J. SUTER

Summary

The genus *Tasmanocoenis* Lestage is redescribed and nymphs directly associated with adults of *T. tonnoiri*, the type species, are described. Nymphal characterization of *Tasmanocoenis* is given. The recently established genus *Pseudocaenis* Soldán is shown to be congeneric with *Tasmanocoenis* and is suppressed.

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KEY WORDS: *Tasmanocoenis*, Ephemeroptera, Caenidae, *Pseudocaenis*, nymphal characterization

Introduction

Prior to 1978 the Caenidae was considered to be represented in Australia by only one genus, *Tasmanocoenis* Lestage (1930) (Demoulin 1955; Thew 1960; Williams 1968; Riek 1970; Suter 1979; and Williams 1980). However, Soldán (1978) established a new genus, *Pseudocaenis* based only on nymphal material from one locality in Queensland, and one in New South Wales. The description of this new genus was based on a comparison with descriptions given by Harker (1950, 1957) of nymphs of *Tasmanocoenis*.

In a recent study of South Australian mayflies, Suter¹ reared imagoes from nymphs referable to *Pseudocaenis*. The adults were typical *Tasmanocoenis*. These observations suggested that the genera were synonymous. Examination of material of all described species of *Tasmanocoenis* (with the exception of *T. jillongi* Harker) and *Pseudocaenis* demonstrated that the generic diagnosis given for *Pseudocaenis* (Soldán, 1978) clearly characterized *Tasmanocoenis*. Therefore *Pseudocaenis* is suppressed and becomes a synonym of *Tasmanocoenis*.

Materials and Methods

Nymphs and adults were associated in the laboratory, and the reared adults were preserved with their individual cast skins. Dissected appendages were mounted in polyvinyl lacto-phenol mounting medium.

All measurements are given in mm. Each segment of the fore, middle and hind legs of the nymph is compared to the length of the femur, as a ratio. The absolute length of the femur is given in parentheses. Comparative measurements of the segments of the labial and maxillary palpi are also expressed as ratios, compared with the proximal segment length, given in parentheses.

In figures of the labium, the method of Peters & Edmunds (1964, 1970, 1972) is followed, with the ventral surface shown on the left.

Material examined was made available from l'Institut Royal Des Sciences Naturelles de Belgique (I.R.Sc.N.B.) and the National Museum of Victoria (NMV).

Genus *TASMANOCOENIS* Lestage

Tasmanocoenis Lestage, 1930, p. 53. Type species *Tasmanocoenis unnoiri* Lestage, original designation.

Lestage, 1930: 53-54; Tillyard, 1936: 56 (Part in *Caenis*); Harker, 1950: 24-26, 29 (referred to as *Caenis*); 1954: 266 (referred to as *Tasmanocoenis* sic, part in *Caenis*); Demoulin, 1955: 4-7; Harker, 1957: 76; van Bruggen, 1957: 32-33; Thew, 1960: 202; Riek, 1970: 238; Puthz, 1975: 412; Soldán, 1978: 124-128; Suter, 1979: 82.

The genus *Tasmanocoenis* was established by Lestage (1930) when *T. tonnoiri* was described from a single adult specimen collected at Geeveston, Tasmania by Tonnoir in 1922. The description was not illustrated and no nymphs of this species were recorded. In 1936, Tillyard described a further caenid species from Tasmania (*Caenis scotti*) but Lestage (1938) noted that the specific name was pre-occupied, and renamed this species *Caenis tillyardi* (sic).

Harker (1950), apparently unaware of Lestage's paper, maintained *Caenis scotti* for the species described by Tillyard, and

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¹ Suter, P. J. (1980) The taxonomy and ecology of the Ephemeroptera (Mayflies) of South Australia. Ph.D. thesis, Dept. of Zoology, University of Adelaide, Unpubl.

described a nymph and female imago which she assigned to this species. These nymphs were not directly associated with a male imago, and there remains some doubt about the identification of the nymph described.

Demoulin (1955) reviewed the Australian Brachycercidae (Caenidae) and re-described, with illustrations, *Tasmanocoenis tonnoiri*, the type species of the genus. He recognised that *Caenis tillyardi* belonged to the same genus as *T. tonnoiri*. Demoulin also presented a key to the genera of adult and nymphal caenids. He based the generic separation of adults on the length and width of the prosternum, length of the antennal pedicel, and length of leg segments, especially the comparative lengths of the fore tibiae and tarsi. The nymphs of *Tasmanocoenis* were distinguished from other genera by having a three or four segmented first gill. This, and the following characters were mentioned by Demoulin as interpreted from Harker's (1950) description and illustrations: gill II not joining at the mid dorsal line of the abdomen, lamellate gills III-VI fringed with tracheal filaments generally simple, rarely bifid; anterior margin of labrum with a median concavity, and denticles on each side of the concavity; second segment of maxillary palp almost as long as third segment; glossae and paraglossae of labium widely separated. The nymphal characteristics were therefore established not from actual specimens, but from Harker's illustrations and descriptions of *T. tillyardi*.

Thew (1960) revised the genera of the Caenidae and listed the following nymphal characteristics as distinguishing *Tasmanocoenis* from other genera: mandibles lacking marginal fringes on both sides; maxillae with only a few hairs, no thick spines; labrum lacking marginal fringe of hair; gill covers without triangular ridge and without marginal fringe of hair; first gill three or four segmented and lamellate gills with fringe of single or bifid tracheal filaments. Soldán (1978) also noted these characters, all of which are consistent with Harker's (1950) illustrations.

Suter¹ questioned the status of *Pseudocaenis* when adults of *Tasmanocoenis tillyardi* were reared from nymphs which displayed characteristics used by Soldán (1978) to define *Pseudocaenis*. To establish the status of *Pseudocaenis* it was necessary to examine the type species of each genus in either adult or nymphal stage. Nymphs were collected and

reared from the type locality of *T. tonnoiri* (Geeveston, Tas.) but all were *T. tillyardi*. However, material from the La Trobe River and the Tyers River, Vic., enabled association of nymphs and adults of *T. tonnoiri*. Examination of this material, the holotype of *T. tonnoiri*, and paratypes of *P. queenslandica* and *P. rieki* Soldán, show that the generic criteria of Demoulin (1955), Thew (1960), and Soldán (1978) for *Tasmanocoenis* are erroneous, and that the characterization given for *Pseudocaenis* (Soldán, 1978) is actually that of *Tasmanocoenis*. The genus *Pseudocaenis* thus becomes a synonym of *Tasmanocoenis*. *Tasmanocoenis* is redefined based on examination of the holotype, and nymphs associated with male imagos of the type species, and of associated adult and nymphal material of *T. tillyardi*.

Imago Characteristics

Male: body length 3.1–4.2 mm, forewing length 2.9–4.0 mm.

Female: body length 5.0–6.5 mm, forewing length 4.5–5.2 mm. Head: eyes separate, lateral. Dorso-lateral ocelli raised, black; median ocellus small, black. Antennal pedicel twice length of scape. Thorax: robust, dark black/brown. Pronotum narrower than head. Prosternum triangular, apex truncate, lateral margins separated, slightly longer than broad. Mesonotum strongly humped, slightly broader than head, median notal suture divided just anterior to wings to form pale area. Legs: pale grey, slender and delicate; forelegs longer than middle and hind legs. Fore, middle and hind legs of male with five tarsal segments; female with all tarsi four segmented. Tarsal claws of male imago similar in foreleg, both blunt and club shaped, dissimilar in middle and hind legs, one blunt, club shaped, one slender, curved and sharp. Female with each pair of tarsal claws dissimilar: one blunt, one curved and sharp.

Wings: forewing length 1.7–2.0 × width; hyaline with milky-opaque pterostigma. Venation reduced, almost lacking cross veins, posterior margins lined with very fine setae.

Mature Nymph Characteristics

Head smooth, lacking protuberances. Pedicel of antenna 2–3 × length of scape, covered with long setae. Tentorial body rectangular, length 0.75 × width. Gills, six pairs on abdominal segments 1–6: first abdominal gill filamentous, two-segmented with long setae;

second gill operculate with triangular dorsal ridge, mesal fork with bifid setae, posterior ridge not extending to posterior margin of gill cover, margin lined with setae; gills 3-6 triangular, pigmented between trachea (pigment may be lost after long preservation), tracheal filaments single to multilid, and with longitudinal band of short bifid bristles on dorsal surface. Second abdominal segment with a small blunt dorsal median spine. Abdominal segments 3-9 with postero-lateral projections.

Mouthparts: labrum rectangular, 2-3 \times broader than long, anterior margin with shallow median concavity, lateral and anterior margins with spine setae. Mandibles stout, with marginal setae, outer incisors with 3-4 teeth, inner with 2-3. Glossae of hypopharynx not produced, anterior margin concave, paragnaths lined with setae. Maxillae slender, with group of teeth at apices, palpi three-segmented. Labium with 3-segmented palpi. Leg margins lined with spine setae, femur of fore leg with transverse row of setae on outer lateral edge, tarsal claws short, curved with blunt teeth near base, and smaller distal teeth. Male and female nymphs similar, but females more robust.

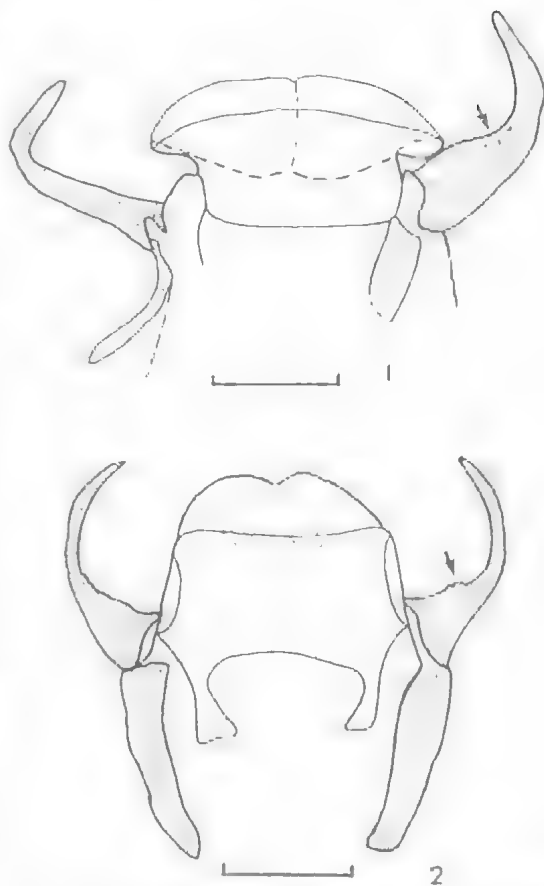
Tasmanocoenis closely resembles *Caenis* in both nymphal and imaginal characters, but the following combination of characters distinguishes *Tasmanocoenis* from all other genera in the Caenidae. In the nymph: (i) pedicel of antenna with setae, (ii) mesal fork of gill cover with bifid setae, (iii) posterior ridge not extending to posterior margin of gill cover, (iv) tarsal claws with blunt teeth near base and smaller distal denticles, (v) submarginal row of scales on gill cover. Male imago: (i) forceps strongly bowed (ii) lobes of penes fused, with apical indentation.

Tasmanocoenis tonnoir Lestage

FIGS. 1-13

Lestage, 1930: 53-54; Tillyard, 1936: 56; Harler, 1954: 266; Demoulin, 1955: 2-3; Thew, 1960: 202.

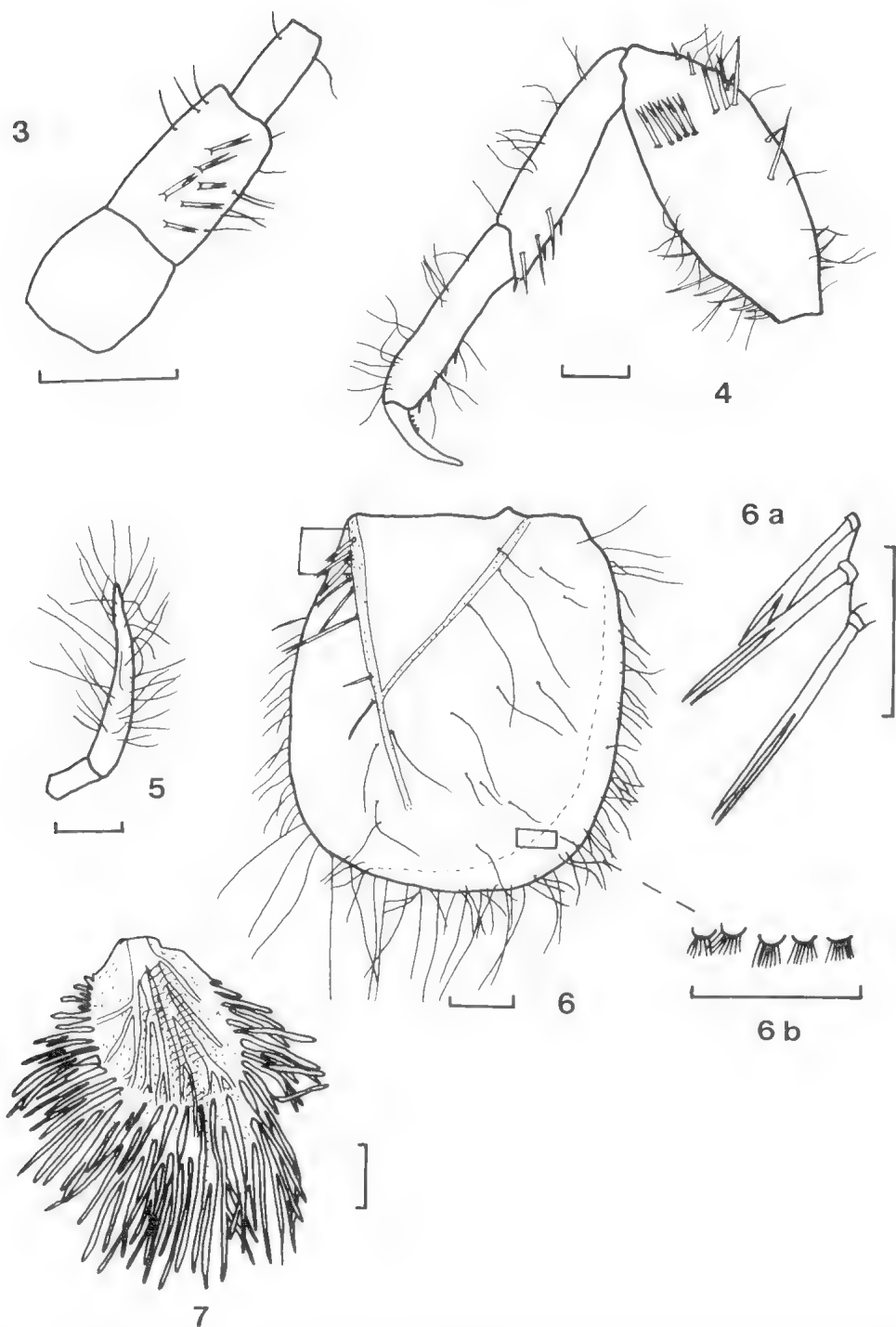
This species was described by Lestage (1930), from a dry specimen glued to a card; no illustrations were given. Demoulin (1955) redescribed the holotype, and mounted the genitalia, legs and wings onto slides, and placed the body in spirits. In the present study the holotype was examined, and although Demoulin's description (with the exception of the genitalia) is adequate, fresh material has



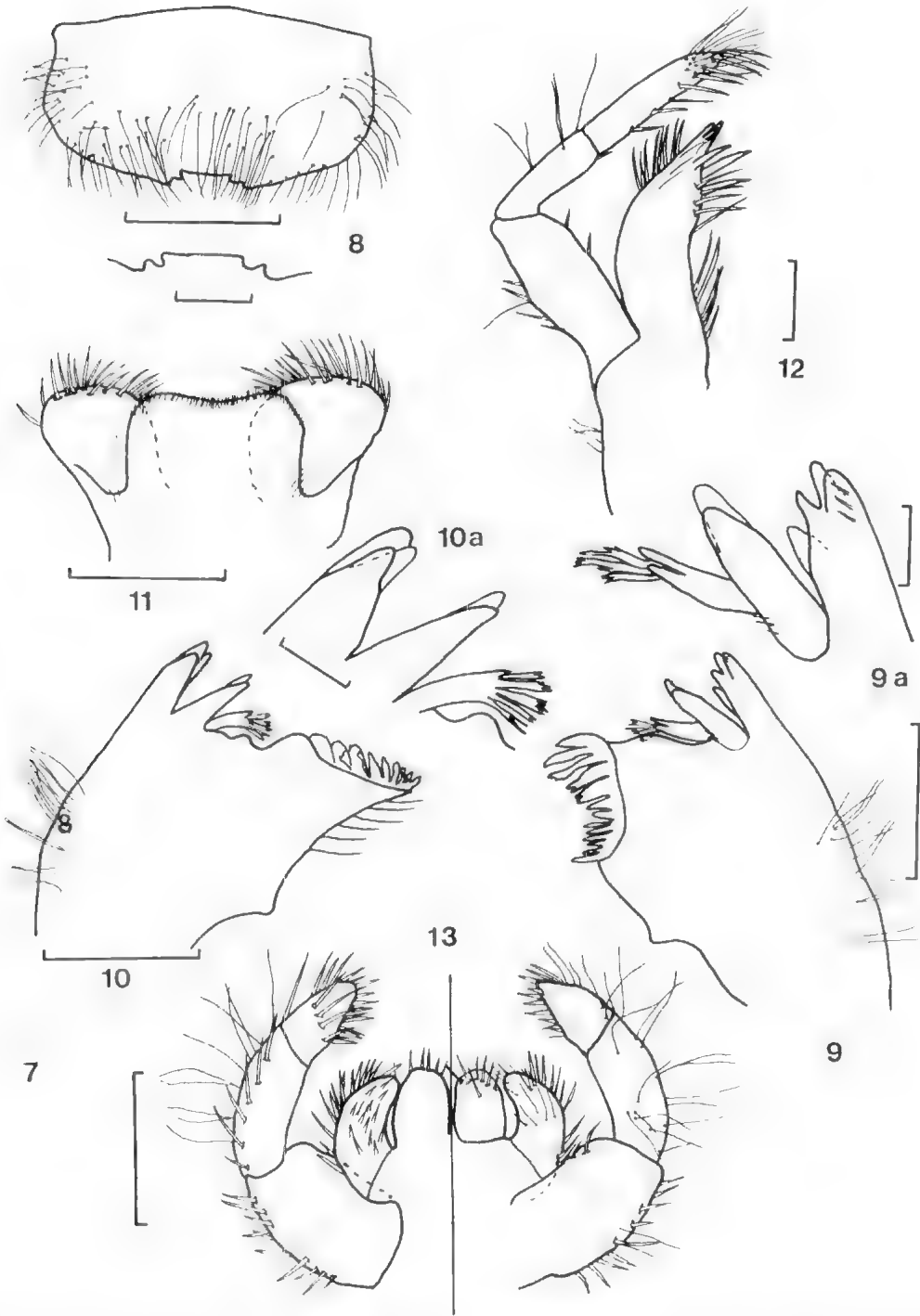
Figs 1-2. *Tasmanocoenis tonnoir*: 1, Genitalia of holotype male, showing the distorted penes and forceps; 2, Genitalia of a male imago from the La Trobe River, Vic. The small basal tubercles are indicated by the arrows. Scale lines = 0.1 mm.

been used to add to this description. Thorax: legs slender, fore femur equal in length to middle femur, but shorter than hind femur. Ratios of leg segments: fore leg 1.00 : 1.85 : 0.13 : 0.61 : 0.28 : 0.32 : 0.19 (0.54 mm); middle leg 1.00 : 0.68 : 0.11 : 0.09 : 0.08 : 0.04 : 0.23 (0.53 mm); hind leg 1.00 : 0.72 : 0.12 : 0.09 : 0.07 : 0.05 : 0.21 (0.58 mm). Genitalia: the genitalia of the holotype, now on a slide, are badly distorted, in parts torn, with the penes folded back within themselves, giving a broad curved posterior margin as illustrated by Demoulin, and in Fig. 1. Genitalia from specimens from the La Trobe River, Victoria, were dissected, and the actual shape of the penes is shown in Fig. 2.

The forceps of the holotype are also twisted and the resultant structures cannot be viewed



Figs. 3-7. *Tasmanocoenis tonnoiri* mature nymph: 3, Basal part of antenna, scape, pedicel, and basal segment of flagellum; 4, Fore leg; 5, First abdominal gill; 6, Second abdominal gill; 6a, Enlargement of the bifid setae of mesal fork of the dorsal triangular ridge; 6b, Enlargement of the submarginal scales; 7, Third abdominal gill. Scale lines; Figs 3, 4, 5 and 7 = 0.1 mm, Figs 6, 6a and 6b = 0.05 mm.



Figs 8–13, *Tasmanocoenis tonnoiri* mature nymph: 8, Dorsal view of labrum with the enlarged antero-medial emargination; 9, Left mandible, ventral view; 9a, Left incisors and prostheca enlarged; 10, Right mandible, ventral view; 10a, Right incisors and prostheca, enlarged; 11, Hypopharynx; 12, Right maxilla, ventral view; 13, Labrum, dorsal (left) and ventral (right) view. Scale lines 0.1 mm.

in ventral orientation. However, along the mesal margin of the forceps are 3 small tubercles. These are also present on the forceps of the holotype, but appear as ventral tubercles (Fig. 1).

The narrow, strongly bowed forceps with 3 mesal tubercles and the shape of the penes are diagnostic characteristics of *T. tonnoiri*.

Mature Male Nymph

The following description is based on one individual, but the range of variation observed in the examined material is given in parentheses.

Head width 0.70 mm (0.70–0.94 mm); body length 2.62 mm (2.62–4.15 mm); cerci length 1.99 mm (1.99–2.35 mm); terminal filament 2.64 mm (2.64–2.88 mm).

General body colour brown.

Head: brown with darker regions between eyes, lateral margins smoothly convex. Eyes black, ocelli brown. Antennae yellow-brown, pedicel $2.60 \times$ length of scape (Fig. 3), flagellum 1 mm long.

Thorax: pronotum brown, antero-lateral margins with few spine setae, width equals head width. Mesonotum dark brown, width $1.5 \times$ head width. Legs light brown; femora without dark markings (Fig. 4).

Ratios of leg segments: fore leg 1.00 : 0.72 : 0.56 (0.57 mm); middle leg 1.00 : 0.71 : 0.50 (0.56 mm); hind leg 1.00 : 0.78 : 0.49 (0.62 mm). Femur length to width ratios: fore leg 2.41 (2.30–2.63), middle leg 2.48 (2.33–2.63), hind leg 2.63 (2.52–2.75).

Abdomen: brown. Operculate gills extending over segments 3–7. Cerci and terminal filament dark brown. Gills; first gill (Fig. 5) apical segment length $3.7 \times$ basal segment length, lined with setae. Second gill operculate, length $1.16 \times$ width (Fig. 6), mesal fork of triangular ridge with 8 bifid setae (range 7–10) (Fig. 6a); submarginal row of scales each with 8–10 bristles present (Fig. 6b). Gills 3–6 triangular with multifid tracheal branches (Fig. 7).

Mouthparts: labrum (Fig. 8) $2.03 \times$ broader than long. Left mandible (Fig. 9) outer incisors with 4 teeth with short setae on ventral tooth (Fig. 9a), inner incisors with 3 apical teeth with short setae on ventral tooth, prostheca robust, bifid with bifid or trifid setae apically. Right mandible (Fig. 10), outer incisors with 3 apical teeth, inner incisors with 2 teeth (Fig. 10a), prostheca simple apically with bifid and trifid setae; margin

between prostheca and molar region with large tubercle. Hypopharynx (Fig. 11). Maxillae (Fig. 12), galeo-lacinia with 4 apical teeth, palpi longer than galeo-lacinia, segment ratios 1.00 : 0.70 : 1.00 (0.14 mm).

Labium (Fig. 13) proximal segment of palpi $1.64 \times$ longer than broad; second segment convex; distal segment short, triangular; segment ratios 1.00 : 0.84 : 0.49 (0.13 mm); glossae rectangular, rounded apically, paraglossae curved.

Material examined: holotype male, Geeveston, Tas., 7 Dec. 1922, A. L. Tonnoir, in I.R.Sc.N.B.

La Trobe River, Rosedale, Vic. 10.ix.1980, R. H. Norris and P. Mitchell (nymphs and adults) in NMV; 27.ii.1974, J. Blyth (nymphs) in NMV; Tyers River, west of Tyers, Vic., 24.ii.1974, J. Blyth (nymphs) in NMV.

Discussion

With this redefinition of the genus *Tasmanocoenis* the following species are now recognised in Australia; *T. tonnoiri* Lestage, *T. tilliardii* (Lestage), *T. jillongi* Harker, *T. queenslandica* (Soldán), and *T. rieki* (Soldán). The latter two species were described in the nymphal form only, but on examination of paratype material presented to the National Museum of Victoria, the two nymphal paratypes are indistinguishable. The characters listed by Soldán (1978) to distinguish the two species do not separate the paratypes. However, on the limited material available, and in the absence of reared adults, a synonymy of *T. queenslandica* and *T. rieki* would be premature, but some doubt must remain as to the validity of these species.

Acknowledgments

I would like to thank Dr G. Demoulin of l'institut Royal Des Sciences Naturelles de Belgique for making available the holotype of *Tasmanocoenis tonnoiri*, and Dr T. Soldán for depositing paratype material of *Pseudocoenis queenslandica* and *P. rieki* in the National Museum of Victoria. I would also like to thank Dr R. Norris and Messrs J. Blyth, P. Mitchell and L. Metzeling for collecting the material from the La Trobe River and for assistance in rearing the adults of *T. tonnoiri*. I am also grateful to Dr A. Neboiss, Dr A. Calder and Dr D. Towns for their critical discussions and suggestions in the preparation of this manuscript.

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A NEW SPECIES OF GEHYRA (REPTILIA: GEKKONIDAE) FROM NORTHERN WESTERN AUSTRALIA

BY MAX KING

Summary

Specimens of an undescribed form of Gehyra are compared with populations of *G. australis* found in adjacent areas of the Kimberley in Western Australia and are described as a new species of the *G. australis* species group.

A NEW SPECIES OF *GEHYRA* (REPTILIA: GEKKONIDAE) FROM NORTHERN WESTERN AUSTRALIA

by MAX KING*

Summary

KING, M. (1984) A new species of *Gehyra* (Reptilia: Gekkonidae) from northern Western Australia. *Trans. R. Soc. S. Aust.* **108**(2), 113-117, 12 June, 1984.

Specimens of an undescribed form of *Gehyra* are compared with populations of *G. australis* found in adjacent areas of the Kimberley in Western Australia and are described as a new species of the *G. australis* species group.

KEY WORDS: New species, *Gehyra*, Gekkonidae, Kimberley.

Introduction

A karyotypic analysis of population of the widely distributed, and morphologically diverse Australian gekko *Gehyra australis*, revealed considerable chromosomal heterogeneity. Seven chromosome races occur in northern Australia: $2n = 44$, $2n = 42A$, $2n = 42B$, $2n = 42C$, $2n = 40A$, $2n = 40B$ and $2n = 38$ (King 1982, King 1983a). Each chromosome race is allopatrically distributed, either geographically or because of habitat preferences. These isolated forms are chromosomally monomorphic for a series of fixed differences. In areas of possible contact between chromosome races, there is no evidence of hybridization.

A subsequent morphometric analysis of the $2n = 42A$, $2n = 42B$, $2n = 42C$, $2n = 40A$ and $2n = 38$ chromosome races (King 1982, King, 1983b) has greatly modified our concept of *Gehyra australis*. This species was redefined and its new distribution was shown to approximate that of the $2n = 40A$ chromosome race (King 1983b). It is therefore now restricted to the northern sector of the Northern Territory, and a small area of northern Western Australia. *G. dubia* Macleay was resurrected to accommodate the $2n = 42C$ chromosome race and the following new species were described: *G. punela* ($2n = 42A$); *G. robusta* ($2n = 42B$) and *G. barroobala* ($2n = 38$) (King 1982, 1983b). Too few specimens of the $2n = 40B$ and $2n = 44$ races were available for a taxonomic reappraisal of these forms to be made.

The present paper describes the results of a morphometric analysis of specimens of the $2n = 44$ chromosome race of *Gehyra*, and of

populations of *G. australis sensu stricto*, from northern Western Australia. A new species is described.

Materials and Methods

Three specimens karyotyped by King (1983a) were measured, as were an additional seven museum specimens which were morphologically identifiable as belonging to the $2n = 44$ chromosome race. These animals were compared with 27 individuals of *G. australis* from adjacent areas of the Kimberley. The distribution of the animals examined is shown in Fig. 1.

All specimens were measured with micrometer-adjusted callipers and a steel rule. Dimensions taken in this study are those of King (1983b).

Results

The specimens analysed fell into two unambiguously distinguishable morphological groups. One of these groups comprised typical *G. australis*, although certain minor variations

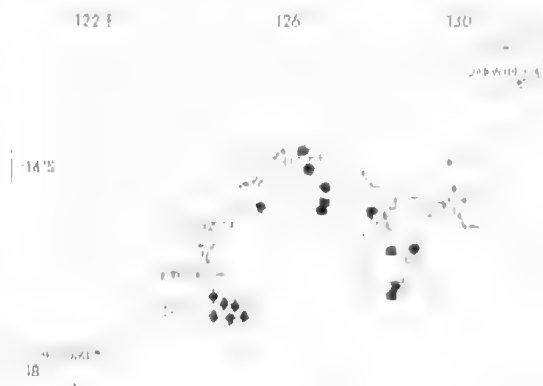


Fig. 1. Distribution of *Gehyra occidentalis* (diamonds) and *G. australis* (black spots).

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(see later), were detected. The second group of ten specimens represented an undescribed form, some of which had been karyotyped by King (1983a) and shown to have $2n = 44$. This form is described here.

***Gehyra occidentalis* sp. nov.**

FIGS 1–5

Gehyra australis part.: King 1983a p. 723.

Gehyra australis part.: King 1983b in press.

Diagnosis: *Gehyra occidentalis* is distinguished from other members of the *G. australis* species group by the following combination of characteristics. It differs from *G. baliola* in lacking a 'U' shaped rostral scale, and by the absence of skin folds on the back of each hind limb. It is distinguished from *G. xenopus* by the absence of basal granules dividing the fourth toe subdigital lamellae. *G. occidentalis* is distinguished from *G. australis*, *G. robusta* and *G. dubia* by having longer postmental scales. Males of these species and of *G. borroloola* have fewer than 19 preanal pores, whereas, *G. occidentalis* has 23–49 pores. *G. occidentalis* is most similar to *G. pamela* from which it is distinguished by the following characteristics: the rostral scale is deep and its dorsal surface strongly gabled, in *G. occidentalis*, whereas it is oblong and slightly gabled in *G. pamela*; when viewed from below the rostral scale projects forward of the snout line in *G. pamela*, but not in *G. occidentalis*; the background colouration of the back pattern is chocolate brown in *G. occidentalis* and grey in *G. pamela*. In those specimens of *G. occidentalis* with pronounced patterning, bands of black spots predominate in size over the interbands of lighter spots. In *G. pamela* the bands of off-white spots form the predominant coloured bands, the darker spots being reduced in size.

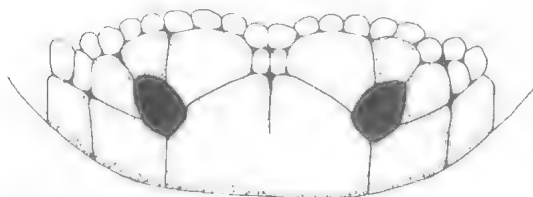


Fig. 2. Diagrammatic representation of the snout of *G. occidentalis* showing the steeply gabled rostral scale, and two small internasals lying between the larger internasals.

Description:

Holotype: Male W.A.M. R83711. Collected on a rock face at night in Manning Gorge, W.A. ($16^{\circ}44'S$, $125^{\circ}57'E$) by D. R. King on 3.xii.1980.

Head: Width 11.0 mm, depth 6.1 mm, length 14.0 mm. Snout 6.1 mm long from tip of rostral scale to anterior margin of orbit. Face and head covered by small rounded scales, those on face larger than on top of head. 33 interorbital scales. Nostril surrounded by rostral, internasal, two posterior nasal and first supralabial scales. Rostral scale oblong and relatively deep. Dorsal surface of rostral steeply gabled to midline apex (Fig. 2). Median groove on rostral extending for 1/3 of scale depth from middle of dorsal surface. Nostrils separated by two large internasal scales. Two very small internasal scales located at apex of rostral separating large internasal scales (Fig. 2). Nine supralabial and eight infralabial scales on each side of jaw. Mental scale triangular. Postmental scales long (3.3 mm) and not in contact with second infralabial scale (Fig. 4b).

Body: Depressed, slender build (Fig. 3). Snout vent length 59.4 mm, tail length 65.00 mm. Tail round in section tapering into a point. Larger scales on ventral surface. Dorsal surface of body covered by small rounded scales. Scales on ventral surface larger and flatter than those on dorsal surface. 126 scales around circumference of abdomen in midbody. Nine subdigital lamellae on dilated section of fourth toe. Subdigital lamellae divided along midline (Fig. 4c). 29 preanal pores in chevron formation in front of cloaca (Fig. 4d). Two postnatal tubercles in cluster at base of tail on each side.

Colouration: Background dorsal colouration chocolate brown in life. Head and faces with alternate very dark brown and off-white spots, separated by background colour. Two parallel eyestripes extending from snout and finishing above ear. Back pattern consisting of bands of black spots (which have coalesced to form



Fig. 3. Holotype of *G. occidentalis* in life. Bar scale = 10 mm.

bars) interspaced by bands of off-white spots. Bands of spots separated by chocolate brown background. Alternate coloured bands like those on the dorsal surface extending along length of tail. Limbs spotted with black and off white (Fig. 3).

Paratypes: There are 9 paratypes: W.A.M. R83712 14°53'S, 125°45'E. W.A. 27.vii.82, collected by J. Dell, W.A.M. R83713 32 km E of turnoff to Napier Downs on Gibb River road, W.A. 27.viii.80 collected by D. King, W.A.M. R45009 Napier Range 170°18'S, 124°50'E W.A. 1.xi.73 collected by W. H. Butler, W.A.M. R70587 11.5 km S.E. of Mt Percy, W.A. 17.v.80 collected by G. Harold, P. Griffin and G. Barron, W.A.M. R70553 8.6 km S.E. of Mt Amy (Napier Downs) W.A. 18.v.80 collected by G. Harold, P. Griffin and G. Barron, W.A.M. R70664 8.6 km S.E. of Mt Amy (Napier Downs) W.A. 18.v.80 collected by G. Harold, P. Griffin and G. Barron, W.A.M. R58757-9 Wombarella Creek, Napier Range, W.A. 9.xi.76 collected by R. E. Johnstone.

Distribution: The known distribution of *G. occidentalis* is restricted to the western section of the Kimberley division of W.A. Populations extend from the Mitchell Plateau in the north to the Napier Range in the south. *G. occidentalis* is an exclusively rock dwelling form, most specimens having been collected on rock faces at night.

Variation: The range of variation in a series of morphometric and meristic characteristics of

G. occidentalis and *G. australis* from the Kimberley, are shown in Table 1. Specimens of *G. occidentalis* always have longer postmental scales than those of *G. australis* of comparable snout-vent length (Fig. 5). Males of *G. occidentalis* are also readily distinguished from *G. australis* by the higher number of preanal pores (23-49 compared to 11-19). Moreover, *G. occidentalis* has fewer fourth toe subdigital lamellae (9-10) than *G. australis* (10-12). The lamellae are completely divided in *G. occidentalis* but only depressed in the midline in *G. australis* (Fig. 4c).

The 27 specimens of *G. australis* examined here show certain differences from the 49 N.T. animals analysed by King (1983b). Kimberley specimens tend to be larger (x S.V.L. 68.7 mm compared with x 60.6 mm) although this may be due to a sampling bias. Specimens from the Kimberley are slimmer in appearance and often have eyestripes, a feature absent from the N.T. populations. They also have more preanal pores in males ($\bar{x} = 16.5$ compared to $\bar{x} = 13.5$), and a larger number of subdigital lamellae on the dilated section of the fourth toe ($\bar{x} = 11.4$, range 10-12 compared with $\bar{x} = 10$, range 9-12). *G. australis* were found on human habitation or on trees in the N.T. whereas those in the Kimberley were also found on rock outcrops. These differences may

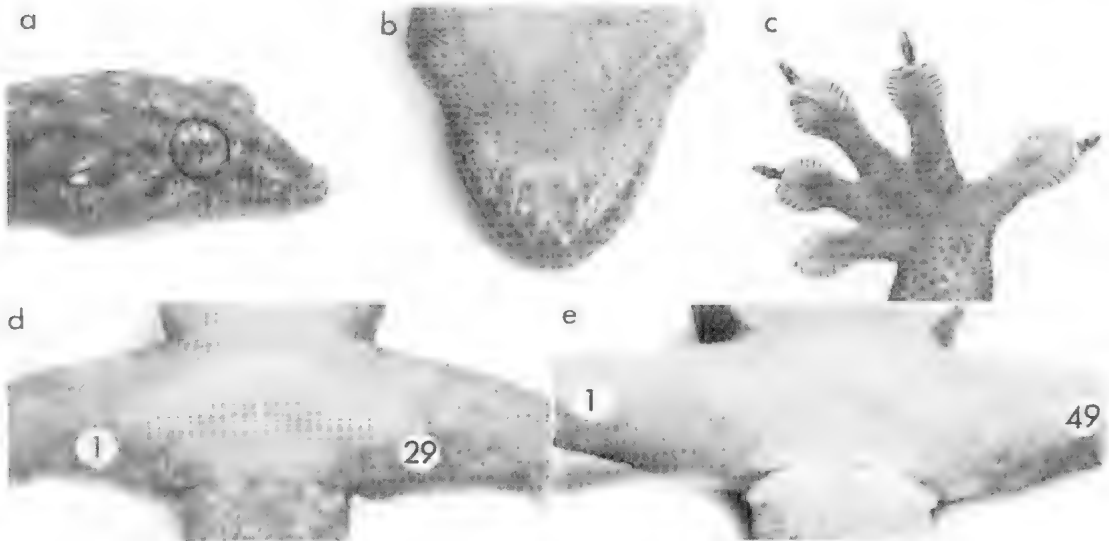


Fig. 4a. Side view of the head of the holotype of *Gehyra occidentalis*.
 b. A ventral view of the snout of the holotype showing large postmental scales.
 c. Ventral view of the foot of the holotype showing divided subdigital lamellae.
 d. Ventral view of the holotype with 29 preanal pores indicated.
 e. Ventral view of a specimen of *G. occidentalis* with 49 preanal pores indicated.

TABLE 1. *Morphometric and meristic characteristics of G. occidentalis and G. australis. Means with ranges in parentheses.*

	N	snout vent mm	tail length mm	snout length mm	postmental length mm	head width mm	head depth mm	head length mm
<i>G. occidentalis</i>	10	58.9 (48-67.3)	— (up to 64)	6.8 (5.6-7.5)	3.5 (2.9-3.9)	12.2 (10.1-14.2)	7.0 (5.9-8.3)	15.2 (12.9-16.5)
<i>G. occidentalis</i>		midbody scales 112.2 (96-126)	interorbital scales 32 (26-36)	preanal pores 30 (6♂) (23-49)	postanal tubercles 2.5 (6♂) (2-4)	subdigital lamellae 9.7 (9-10)	supra- labials 9.2 (8-11)	infra- labials 8.4 (7-10)
	N	snout vent mm	tail length mm	snout length mm	postmental length mm	head width mm	head depth mm	head length mm
<i>G. australis</i>	27	68.7 (58.6-75.0)	— (up to 84)	7.3 (5.7-8.1)	3.0 (2.1-3.5)	13.0 (11.2-14.6)	7.7 (6.7-8.7)	16.6 (14.1-18.0)
<i>G. australis</i>		midbody scales 117.6 (102-131)	interorbital scales 32.4 (27-37)	preanal pores 16.5 (18♂) (11-19)	postanal tubercles 2.7 (18♂) (1-3)	subdigital lamellae 11.4 (10-12)	supra- labials 10.3 (9-12)	infra- labials 8.7 (7-10)

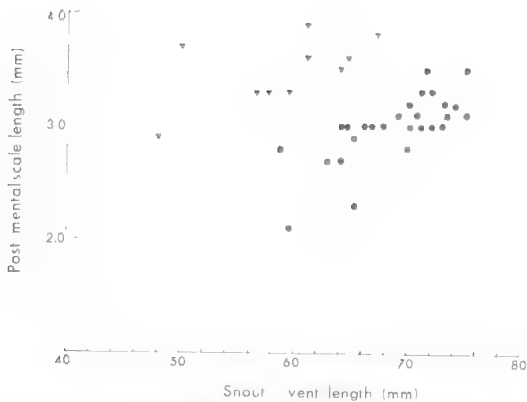


Fig. 5. Postmental scale length plotted against snout-vent length for specimens of *G. occidentalis* (triangles) and *G. australis* (spots).

simply reflect clinical variation within *G. australis*; they are much less profound than the differences which separate *G. occidentalis* from *G. australis*.

G. occidentalis is morphologically most similar to *G. pamela* (King 1982). *G. pamela* is found on the Arnhemland escarpment and probably throughout Arnhemland in the N.T. Both *G. occidentalis* and *G. pamela* have long postmental scales, and a higher number of preanal pores than *G. australis* (up to 28 in *G. pamela*, up to 49 in *G. occidentalis*) (Fig.

4e). A further difference between these species is seen in the morphology of the rostral scale which is deep with a strongly gabled dorsal surface in *G. occidentalis*, and oblong and only slightly gabled in *G. pamela*. When viewed from below, the rostral area projects anteriorly to the snout line in *G. pamela* but not in *G. occidentalis*. In *G. occidentalis* a series of 0(2), 1(4) or 2(4) small internasal scales occur between the large internasals, at the apex of the rostral (Fig. 2). Sometimes one small internasal is seen in *G. pamela*.

G. occidentalis is also distinguished from *G. pamela* by its chocolate brown rather than grey colouration. Some specimens of *G. occidentalis* lack a pronounced back pattern; others are strongly marked, with bands of black spots predominating. In *G. pamela* the dark colours are much less pronounced and the bands of light spots predominate (see Fig. 4a, King 1982). The back pattern of the holotype (Fig. 3) is similar to that of some specimens of *G. borrooloola*, but distinction from that species can be readily made by the rostral shape, and greater number of preanal pores in males. The only other species of *Gehyra* which has a back pattern similar to *G. occidentalis* is *G. cognatus* (Rudiger-Borner & Schuttler, 1982). This species, based on a single specimen shares many characteristics with *G. pilbara*, including the presence of 8 subdigital lamellae (although they are grooved, not divided), 8 supralabials, 6 infralabials and a deepset, blunt-snouted head. The animal was apparently

captured with specimens of *G. pilbara* and on the basis of the published information is probably an unusual *G. pilbara*. In any case, it is not a member of the *G. australis* species complex.

Etymology: The specific name *G. occidentalis* is derived from the Latin "occidentalis" meaning western, and refers to the distribution of this species.

Other material examined: W.A.M. R70153-4, R70156, R70146-8 28 km S.E. Kununurra, W.A., 21.iv.1980. W.A.M. R60345 35 km S.W. Kununurra (Saw Rg.), W.A., 2.vi.1978. W.A.M. R70688 3.5 km N.W. New Lissadell H.S., W.A., 6.v.1980. W.A.M. R44037 Sir Graham Moore Is., Bonaparte Arch., W.A., 2.vii.1973. W.A.M. R27571-4 Parry Ck., W.A., 20.vii.1965. W.A.M. R42788-90 Old Lissadell H.S., W.A., 16.x.1971. W.A.M. R50776-7 Drysdale R. Nat. Pk. 14°40'S, 127°00'E. 9-12.viii.1975. W.A.M. R50794 Drysdale R. Nat. Pk. 14°40'S, 127°00'E. 12.viii.1975. W.A.M. R70451 10.7 km S.W. New Lissadell H.S., W.A., 26.iv.1980. W.A.M. R64919 Drysdale R. Nat. Park 15°08'S, 126°55'E. 3.viii.1975. W.A.M. R64920 Drysdale R. Nat. Pk. 15°03'S, 126°44'E. 18.viii.1975. W.A.M. R50807 Drysdale R. Nat. Pk. 14°40'S, 127°00'E. 14.viii.1975. W.A.M. R50869 Drysdale R. Nat. Pk. 15°02'S, 126°49'E. 18.viii.1975. W.A.M. R50595 Drysdale R. Nat. Pk. 14°46'S, 127°05'E. 14.viii.1975. W.A.M. R50960 Drysdale R. Nat. Pk. 15°02'S, 125°49'E.

14.vii.1975. W.A.M. R13582 Kalunibutu, W.A., 26.vi.1980.

The *Gehyra australis* species group

The *G. australis* species group now comprises *G. baliola*, *G. xenopus*, *G. borroloola*, *G. australis*, *G. robusta*, *G. dubia*, *G. pamela* and *G. occidentalis*.

Karyotypic analysis has shown that these large Northern Australian forms, while being in the same lineage as the other Australian *Gehyra*, have evolved as an independent group (King 1982, 1983a). Their general morphological similarity is accentuated by the fact that six of the species (*G. australis*, *G. borroloola*, *G. robusta*, *G. dubia*, *G. pamela* and *G. occidentalis*) were, until recently, all included as *G. australis*. Adult specimens of this species complex have a snout-vent length of 50-91 mm and at least 9 subdigital lamellae on the dilated area of the fourth toe.

Acknowledgments

The author is indebted to Dennis King, John Dell and Richard How for collecting live specimens of *G. occidentalis* for analysis. I thank Glen Storr and Laurie Smith of the Western Australian Museum (WAM) for providing a series of *Gehyra* for examination.

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FOSSIL MARSUPIAL REMAINS AT THE SOUTHEASTERN CORNER OF LAKE EYRE NORTH, SOUTH AUSTRALIA

BY J. A. DULHINTY, T. F. FLANNERY & J. A. MAHONEY

Summary

Marsupial fossil remains, interpreted as being Pleistocene in age, occur in a restricted deposit lying disconformably on Tertiary dolomite along the eastern side of Price Peninsula at the southeast corner of Lake Eyre North. Fossil remains include *Sthenurus andersoni* Marcus, 1962, *Diprotodon* sp. and *Macropodinae* indet.

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by J. A. DULHUNTY*, T. F. FLANNERY† & J. A. MAHONEY*

Summary

DULHUNTY, J. A., FLANNERY, T. F. & MAHONEY, J. A. (1984) Fossil marsupial remains at the southeastern corner of Lake Eyre North, South Australia. *Trans. R. Soc. S. Aust.* **108**(2), 119-122, 12 June, 1984.

Marsupial fossil remains, interpreted as being Pleistocene in age, occur in a restricted deposit lying disconformably on Tertiary dolomite along the eastern side of Price Peninsula at the southeast corner of Lake Eyre North. Fossil remains include *Sthenurus andersoni* Marcus, 1962, *Diprotodon* sp. and Macropodinae indet.

KEY WORDS: Marsupial fossils, Lake Eyre, South Australia, *Sthenurus*, *Diprotodon*, Macropodinae, occurrence, taxonomy, chronology.

Introduction

In 1980 J. A. and R. Dulhunty found an occurrence of fossil marsupial remains at the southeastern corner of Lake Eyre North. The geological setting of the occurrence was studied by them and bones were examined and identified by T. F. Flannery and J. A. Mahoney during 1981-1982.

The purpose of this paper is to record the location and geological setting of the occurrence, and the taxonomy and chronology of the fossil remains.

Location and geological setting

The fossil remains occur along the eastern shore of Price Peninsula which separates Lake Clayton from Lake Eyre, south of the Frome-Clayton Estuary near Level Post Bay (Fig. 1A). The sediments containing the fossils vary sporadically from lightly compacted sands to semi-consolidated argillaceous, gypsaceous and calcareous sandy mudstone. They crop out as a continuous bed, 2-3 m thick, at and a little above shoreline level along the eastern side of Price Peninsula (Fig. 1B). The bed is referred to informally for field purposes as the "bone bed". It lies disconformably upon the eroded surface of dolomite beds of the Etadunna Formation which crop out along the western side of Lake Clayton and dip generally northwest towards and beneath the bed of Madigan Gulf. Section A-B (Fig. 1C) is a tentative illustration of a structure in Price Peninsula indicated by preliminary field studies. The bone bed is overlain conformably for the most part, but with

minor disconformities, by semi-consolidated clays and argillaceous sands up to at least 13 m thick which crop out across the southern shores of Madigan Gulf above the Etadunna Formation dolomites (Dulhunty 1982, 1983). The geology of Level Post Bay, Price Peninsula and the southern shores of Madigan Gulf was described first by King (1956), and later by Johns (1963) and Williams (1976). To the east of Lake Eyre, the geology of the Tirari Desert was described by Stirton *et al.* (1961). The beds overlying the bone bed are now believed to be Pleistocene age, and the underlying dolomite of the Etadunna Formation is regarded as late Tertiary (Wopfner & Twidale 1967, Wopfner 1974, Callen & Tedford 1976, Callen 1977).

Bores by King (1956) and the South Australian Department of Mines (Johns 1963) on the shore at Level Post Bay revealed the upper surface of Etadunna dolomite at about 4 m below the shoreline level of the bay, but surface outcrops of dolomite along the western and southern shores of Lake Clayton were not recorded. Recent fieldwork by Dulhunty between the western shore of Lake Clayton and Frome Creek (Fig. 1A) found the upper surface of dolomite cropping out at about 4 to 6 m higher than in Level Post Bay. This indicated a fault, warp or erosion between Level Post Bay and Lake Clayton (Fig. 1C). A Sparker seismic traverse from Madigan Gulf into the Frome-Clayton Estuary, by C. V. G. Phipps (*pers. comm.*) during the major filling of the lake in 1974, yielded evidence of faulting as indicated in Figure 1A. This, in line with the Price Peninsula structure, could well be part of a lineation running north-north-west which postdated the bone bed and contributed

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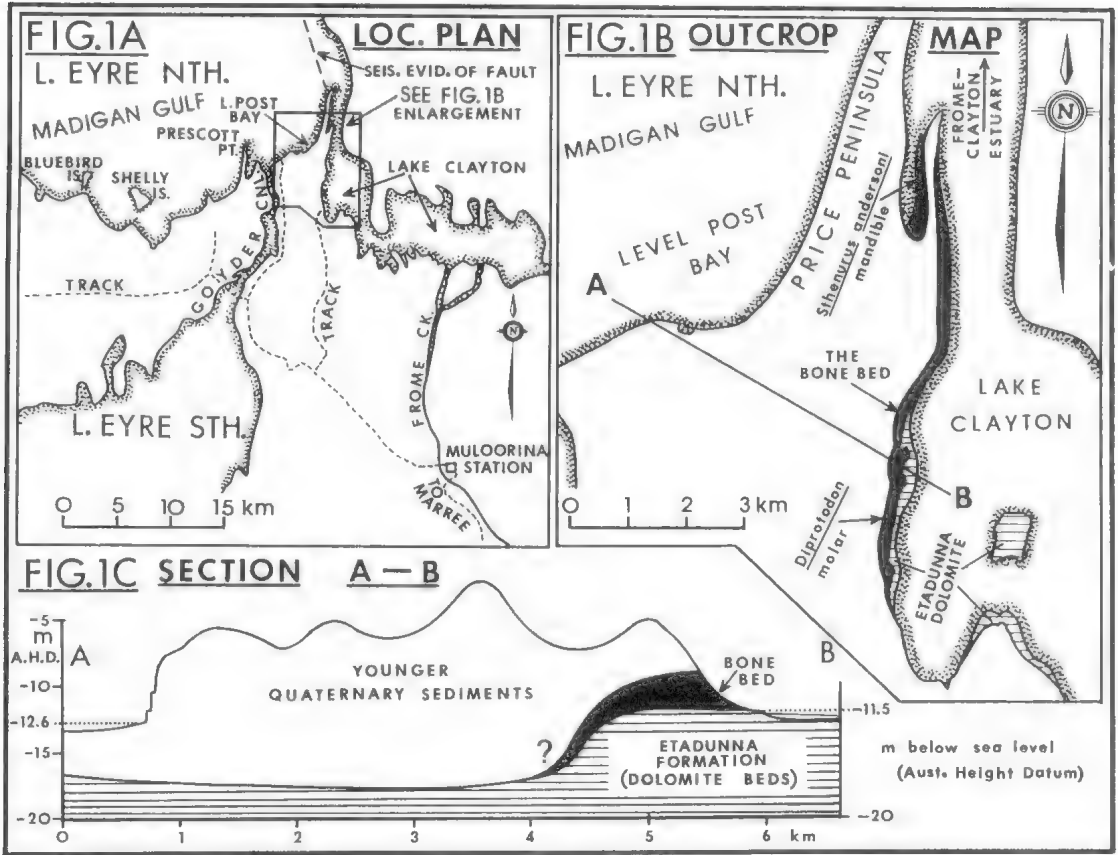


Fig. 1. Occurrence of fossil marsupial remains at the southeastern corner of Lake Eyre North.

to the original position of the shoreline on the eastern side of Lake Eyre.

The bone bed crops out along the western shore of Lake Clayton on the eastern side of Price Peninsula (Fig. 1B). At its limits of outcrop the bed is overlapped by younger sediments onto the eroded surface of dolomite. To the east of its outcrop the bed has been removed by erosion during excavation of Lake Clayton. No bone bed has been found above dolomite surfaces which crop out along the southern shores of Lake Clayton. To the west of its outcrop the extent of the bone bed is obscured by younger sediments and the westerly dip takes the dolomite surface and overlying horizon of the bone bed below the shoreline of Lake Eyre (Fig. 1C). The dolomite emerges again 20 km further west, between Shelly and Bluebird Islands (Fig. 1A), but no fossil marsupial remains have yet been found immediately above its outcrop. In 1982 R. A. Callen found a large vertebrate bone (Callen, *pers. comm.*) in a section above

the surface of the lake bed at Prescott Point, some 8 km west of the bone bed outcrop in Lake Clayton. This bone may have occurred on a horizon above that of the bone bed in Lake Clayton.

From limited field evidence available it would seem that the bone bed was very restricted in original area of occurrence, and that it probably terminated by overlap beneath Price Peninsula 1–2 km west of its present outcrop, as shown with query in Figure 1C.

Taxonomy and chronology of fossil remains

The remains of three marsupial taxa have been identified among a small collection of fossil bones and teeth from the bone bed (AM F65475–9). These are *Sthenurus andersoni* Marcus, 1962, *Diprotodon* sp. and *Macropodinae indet.* The specimens are in the Australian Museum, Sydney.

Sthenurus andersoni is represented by a broken mandible with teeth in an advanced stage of wear (Fig. 2) (AM F65476). *S.*

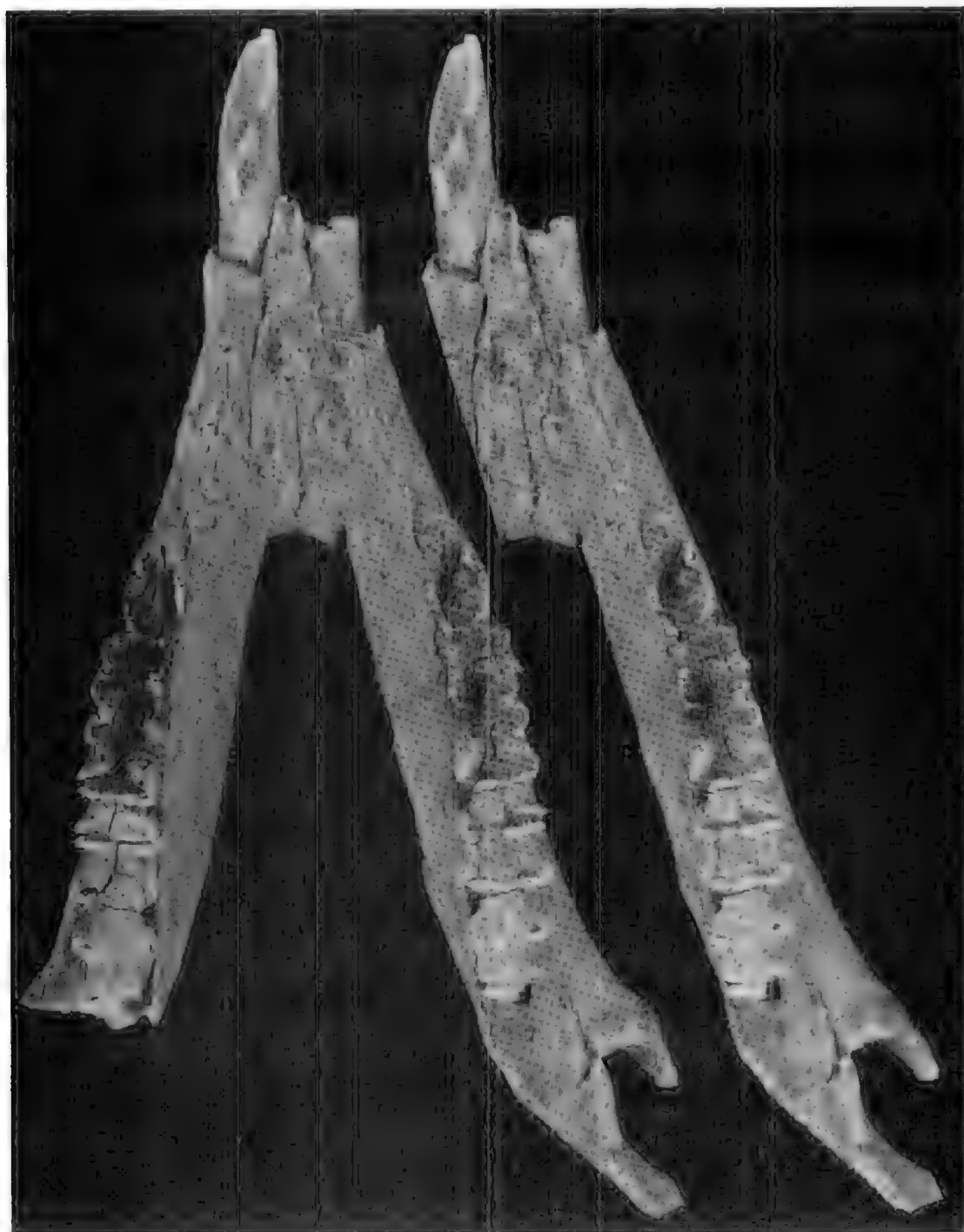


Fig. 2. AM F65476, mandible of *Stenurus andersoni* Marcus, 1962 from the bone bed, southeastern corner of Lake Eyre North, South Australia. Occlusal view (stereopair of right ramus and anterior part of the left ramus). $\times 1.1$.

andersoni can be distinguished from near relatives in the following ways: it differs from the species of *Simosthenurus* Tedford, 1966 in having more gracile dentaries, and in lacking the conspicuous crenulations on the molars. *S. andersoni* is smaller than the other species of *Sthenurus* (*S. tindalei* Tedford, 1966, *S. notabilis* Bartholomai, 1963 and *S. atlas* Owen, 1838). While closest in size to *S. atlas*, *S. andersoni* differs from that species in possessing lower crowned molars with less well-developed linking.

Sthenurus andersoni is known only from sediments of Pleistocene age. It has been recorded from several undated sites in South Australia including, tentatively (as *S. cf. andersoni*), localities along Cooper Creek, northeast of Lake Eyre (Williams 1980). The most recent date for *S. andersoni* is 20 000 years B.P. at Spring Creek, southwestern Victoria (Flannery 1980, Flannery & Gott in press).

Diprotodon Owen, 1838 is a poorly understood genus and it is not possible at present to determine the specific name for most specimens. The *Diprotodon* remains from the bone bed are incomplete, consisting of molar (AM

F65477) and postcranial fragments (AM F65478). As far as it is known, *Diprotodon* is restricted to the Pleistocene. Rich *et al.* (1982) record the genus from the Upper Pliocene, but this is an error (T. Rich *pers. comm.*). Terminal dates for *Diprotodon* are around 25 000 years B.P. at Lancefield, Victoria (Gillespie *et al.* 1978) and 20 000 years B.P. at Spring Creek, Victoria (Flannery 1980).

The macropodine is represented by an astragalus (AM F65479). It is similar in morphology and size to the astragalus of a large species of *Macropus* Shaw, 1790.

The association of species of *Sthenurus* and *Diprotodon* is a characteristic feature of many Pleistocene fossil localities in southeastern Australia. In South Australia such an association has been recorded from several localities along the Warburton River and Cooper Creek near the northeast corner of Lake Eyre as well as from many other parts of the State (Williams 1980). The latest date for sites containing these taxa is about 20 000 years B.P., but some such sites may be up to 2 million years old. On this basis, the Price Peninsula bone bed is interpreted as being Pleistocene in age, but probably older than 20 000 years.

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UPEROLEIA GRAY (ANURA: LEPTODACTYLIDAE) IN NEW GUINEA

BY MICHAEL J. TYLER & MARGARET DAVIES

Summary

Uperoleia lithomoda is reported from New Guinea for the first time. The occurrence of the species across the north of Western Australia, the Northern Territory and Queensland is recorded.

UTEROLEIA GRAY (ANURA: LEPTODACTYLIDAE) IN NEW GUINEA

by MICHAEL J. TYLER & MARGARET DAVIES¹

Summary

TYLER, M. J. & DAVIES, M. (1984) *Uteroleia* Gray (Anura: Leptodactylidae) in New Guinea. *Trans. R. Soc. S. Aust.* 108(2), 123-125, 12 June, 1984.

Uteroleia lithomoda is reported from New Guinea for the first time. The occurrence of the species across the north of Western Australia, the Northern Territory and Queensland is recorded.

KEY WORDS: *Uteroleia*, New Guinea, Cape York Peninsula, Osteology, Distribution.

Introduction

The Leptodactylid (myobatrachid of some authors) genus *Uteroleia* Gray is one of the most poorly known Australopapuan frog genera. Tyler, Davies & Martin (1981a) revised the Australian members of the genus, described nine new species, resurrected two others and raised to 16 the number of species recognised. Subsequently, Tyler *et al.* (1981b,c) described two further new species from Western Australia and the Northern Territory respectively.

Tyler (1972) reported an unidentified species of *Uteroleia* collected by Fred Parker in the southern lowlands of New Guinea, representing the first record of the genus from Papua New Guinea. These specimens are the basis on which Menzies (1975) and Zweifel & Tyler (1982) included the genus in the New Guinea fauna.

Recently we have compared the New Guinea specimens with material from Horn Island (off the tip of Cape York) and from various sites on the Australian mainland. These data demonstrate that the specimens represent *U. lithomoda* Tyler, Davies & Martin. Here we report on the New Guinea specimens and review the distribution of *U. lithomoda*.

Materials and Methods

The specimens reported here are lodged in institutions abbreviated as follows: MCZ Museum of Comparative Zoology, Harvard University; NTM Northern Territory Museum and Art Gallery, Darwin; QNPWS Queensland National Parks and Wildlife Service, Townsville; SAM South Australian Museum, Adelaide.

Methods of measurement follow Tyler (1968). Skeletons were cleared and stained for bone after the method of Davis & Gore (1947). Recordings of male calls were analysed on a Kay Digital Sonograph 7800 and compared with sonograms of *U. lithomoda* published by Tyler *et al.* (1981).

Uteroleia lithomoda Tyler, Davies & Martin 1981

Uteroleia sp.: Tyler, 1972, p. 237.

Material examined: Papua New Guinea: MCZ A106605, Y37616 (cleared and stained), SAM R25425, Moorehead, Western Districts; Australia, Queensland: MCZ A106606, A80234, SAM R25423-24 Horn Island, Torres Strait; QNPWS N28871, Lakefield, N.P., Cape York Peninsula; N32319, Coen, Cape York Peninsula; SAM R4941 Bentinck Island, Northern Territory; NTM R0125, Fogg Dam; R0880-81, 2020-24 Shoal Bay, Darwin; R2885, Berry Springs; R2912, 25 km NE Noonamah; R5868, Mary River, Annaburto Stn; SAM R24011-14, R25110-11, 11 km NE Katherine; R24015-16, Saddle Creek, Victoria Hwy; R24009, 25.6 km E NT/WA border; Victoria Hwy; R25108-9 17 km E Roper River Rd, Stuart Hwy Junction; R25106-7, E end Angurru Airport, Groote Eylandt; R24010 (Desmonds Passage), Victoria Hwy, 409 km W Katherine.

Distributional data from call records:

W.A.: 2.6, 5.3, 7.6, 9.1, 10.0, 10.8, 16.9, 19.3, 21.1, 21.4, 26.1, 26.7, 28.5, 32.4, 33.8, 37.1, 42.1, 60.4 & 89.1 km E of Wyndham township on Wyndham/Kununurra Rd; 9.3 & 43.7 km E Wyndham airport turnoff, Wyndham/Kununurra Rd. NT: 11.2 & 13.3 km E Victoria River on Victoria Hwy; 2.0, 7.6, 9.2, 10.6, 11.1, 12.4, 13.5, 13.8 & 14.4 km E Saddle Crk on Victoria Hwy; 100, 295, 403.9, 406, 406.8, 410.8, 411.5, 413.2 & 415.1 km W Katherine on Victoria Hwy; 18.4 & 20 km W Daly River/Stuart Hwy Jcn, Daly River Rd, 7 km W Mary River, Arnhem Hwy; Mary River Bridge, Arnhem Hwy; Umbakumba, Groote Eylandt.

The two New Guinea specimens are adult females with snout to vent lengths of 19.7 and 23.0 mm respectively. The type series did not include a single female, and the 16 males

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ranged 20.9–25.2 mm (Tyler *et al.* 1981a). Because female frogs tend to be larger than conspecific males, the size of the smallest female from New Guinea might be considered sufficient to question its identity. However, the specimen falls within the range of size varia-

tion in populations in Queensland and the Northern Territory.

Osteologically the single New Guinea specimen cleared and stained (MCZ Y37616), conforms closely with representatives of *U. lithomoda* from the Kimberley Division of

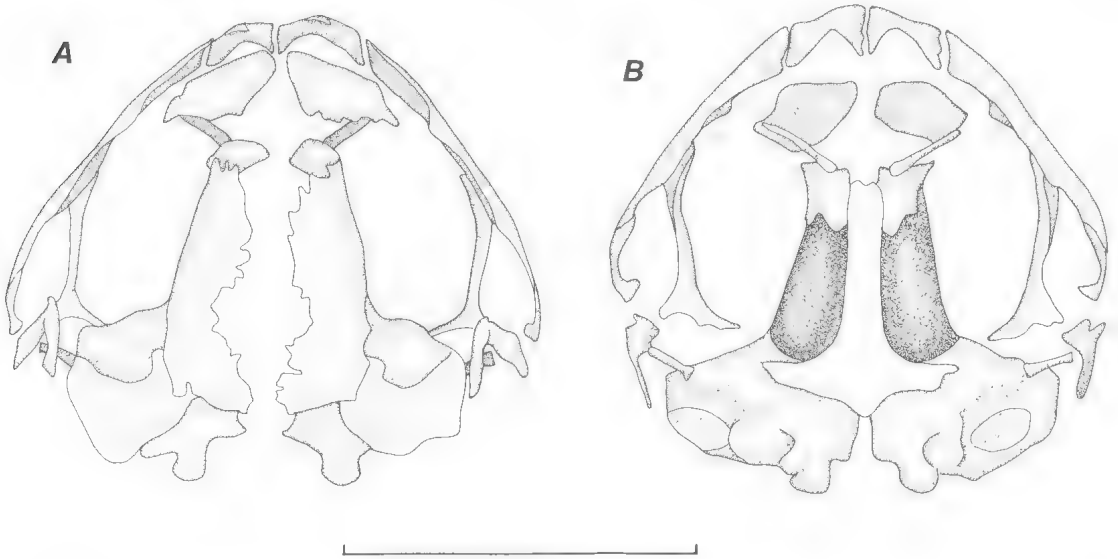


Fig. 1. A Dorsal and B ventral views of the skull of *Uperoleia lithomoda* from New Guinea (MCZ Y37616). Scale bar = 5 mm.



Fig. 2. Distribution of *Uperoleia lithomoda* in Australia and New Guinea.

W.A. Exposure of the frontoparietal fontanelle is greater than that of N.T. specimens illustrated by Tyler *et al.* (1981a) but is similar to the condition exhibited by specimens from the vicinity of the type locality. The medial edges and anterior extremities of the frontoparietals are characteristically crenulated (Fig. 1A). The nasals are triangular and widely separated posteromedially. The zygomatic rami of the squamosals are minute and the medial arm of the pterygoid is characteristically broad and not acuminate. The palatines are slender and reduced laterally, angled to the midline, and the premaxillaries are absent. The maxillary arch is edentate (Fig. 1B).

Call: Parker did not record the call of the New Guinea or Horn Island specimens, but described it as a single, very loud note on Horn Island. This description fits our field observations. The nearest locality where calls have been recorded is Coen on the Cape York

Peninsula (specimen QNPWS N32319; K. R. McDonald). That call is within the parameters of *U. lithomoda* defined in the type description.

Distribution: *Uperoleia lithomoda* ranges from the Kimberley Division of W.A. through the N.T. and Qld to New Guinea (Fig. 2). The wide gaps between some localities probably reflects lack of collecting, or our lack of access to specimens from these areas. We suspect that the distribution will prove to be continuous on the Australian mainland.

Acknowledgments

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WARDANG ISLAND – A REFUGE FOR MARGINOPORA VERTEBRALIS?

BY Y. BONE

Summary

Marginopora vertebralis Blainville is reputed to have become extinct in South Australian waters after deposition of the Glanville Formation although it still flourishes today at Shark Bay, and along the Great Barrier Reef where water temperatures are much higher than in the Southern Ocean. Samples have been retrieved from contemporary bottom sands at Quindalup, Geographe Bay (M. Lindsay pers. comm.) whilst the species has been reported as “rare” at Oyster Harbour near Albany and as “isolated to frequent” in bottom samples from the continental shelf south of the Eucla Basin. On Wardang Island it occurs in the Pliocene Hallett Cove Sandstone with examples up to 2.5 centimetres in diameter, and in lightly indurated beach rock on the 2 metre high stranded beaches (Fig. 1) where it is of the order of ≤ 0.5 centimetres in diameter. This latter material may belong to the Glanville Formation, although extensive searching failed to locate any specimens of species commonly associated with *M. vertebralis* at this time, e.g. *Anadra trapezia* (Deshayes) or *Pinctada carchariarum* Jameson.

WARDANG ISLAND—A REFUGE FOR *MARGINOPORA VERTEBRALIS*?

Marginopora vertebralis Blainville is reputed to have become extinct in South Australian waters after deposition of the Glanville Formation^{1,2}, although it still flourishes today at Shark Bay³, and along the Great Barrier Reef where water temperatures are much higher than in the Southern Ocean. Samples have been retrieved from contemporary bottom sands at Quindalup, Geographe Bay (M. Lindsay *pers. comm.*) whilst the species has been reported as "rare" at Oyster Harbour near Albany⁴ and as "isolated to frequent" in bottom samples from the continental shelf south of the western side of the Eucla Basin⁵. On Wardang Island it occurs in the Pliocene Hallett Cove Sandstone with examples up to 2.5 centimetres in diameter, and in lightly indurated beach rock on the 2 metre high stranded beaches⁶ (Fig. 1) where it is of the order of ≤ 0.5 centimetres in diameter. This latter material may belong to the Glanville Formation⁷, although extensive searching failed to locate any specimens of species commonly associated with *M. vertebralis* at this time,

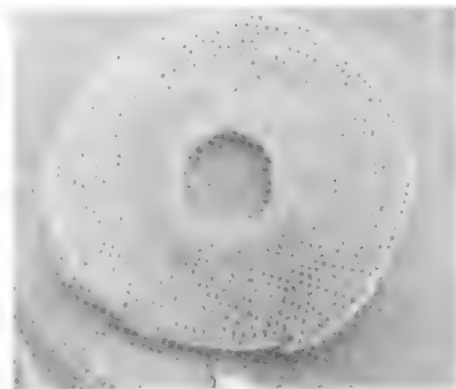


Fig. 2. *M. vertebralis* from tidally deposited detritus on northern beach of Wardang Island. Scale: 1 cm \equiv 1 mm. SEM image.

e.g. *Anadara trapezia* (Deshayes) or *Pinctada carcharias* Jameson.

However, it is also found as complete, ≤ 0.5 centimetre diameter, discrete individuals amongst the daily tidally deposited detritus at the edge of the reef between Wardang Is. and Goose Is. (Fig. 1). Numbers seen in this detritus are of the order of approximately 10 samples/5 metres/30 minutes searching time. Microscopic observation of *M. vertebralis* from this site, the beach rock and the Pliocene from Wardang Is., Glanville Fm, material from St Kilda beach and recently living specimens from the Great Barrier Reef leads one to suspect that this foraminifer may still be extant on the modern Wardang Is. reef. The tests at the latter locality show either none or little evidence of cementation (Fig. 2), and overall, surprisingly little aggradation, suggesting a nearby source. A determined effort to locate the source met with failure, so that it is likely that neither the rocks of the adjacent coast lines of Wardang and Goose Islands nor the reef rock are the source. This leads back to the possibility of the reef being a favourable habitat for the continuing survival of the species after Glanville Formation time.

To further test this hypothesis, a comparative analysis of the Mg content of the tests has been made (Table 1). For each location, 2 specimens were selected, with care paid that they did not contain or have adhering any particles of matrix. These were crushed, taken up into solution in acid and then analysed for Mg by atomic absorption spectrophotometry. The living foraminifer secretes a high-Mg calcite test⁸, which after death and incorporation into the sediment, rapidly inverts to low-Mg calcite by diagenetic processes.

Although the analyses do not prove the hypothesis, they certainly support the suggestion that the reef between Wardang and Goose Islands may

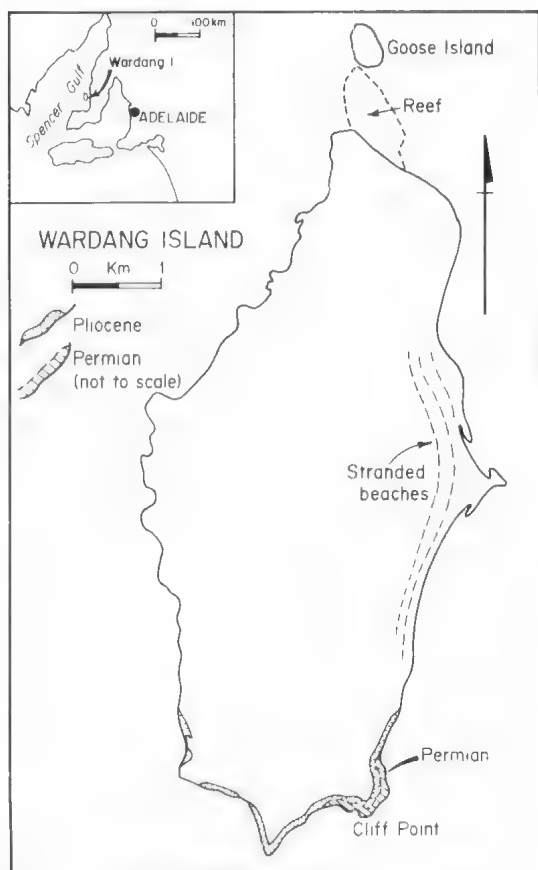


Fig. 1. Locality map.

TABLE 1. Chemical analysis of $MgCO_3$ content of *Marginopera vertebralis*

Location	Age	$MgCO_3\%$
Wardang Island (shore-line detritus)	possibly present	8.99
Great Barrier Reef	present	9.75
Wardang Island (beach rock)	Younger than Glanville Formation	10.31
St Kilda Beach	Glanville Formation	6.27
Wardang Island (S.E. coast)	Pliocene— Hallett Cove Sandstone	3.35

be a refuge for *M. vertebralis*. The high $MgCO_3$ figure for the Wardang Island beach rock is inexplicable, although suggestions such as groundwater influence (1) from high-Mg halophytic vegetation decomposition, (2) from underlying bedrock (R. Oliver *pers. comm.*) or (3) leading to the for-

mation of microscopic dolomite rhombs, as commonly occurs in this type of environment (V. Gostin *pers. comm.*), are all possibilities. Although this high figure downgrades the validity of the hypothesis, the other analyses are nevertheless sufficient to warrant questioning the age of the reef samples, especially when compared to the analyses of 8.8%, 9.55%, 10.50% and 12.52% $MgCO_3$ content quoted for contemporary *M. vertebralis* specimens from Fiji¹⁰. It is desirable that a thorough search be made for living specimens in this area. Care will be needed. Hasty decisions based on protoplasm-staining techniques could be misleading as various algae and bacteria rapidly invade vacated tests.

Due to changing policies regarding the use of Wardang Island, the author has been unable to return and follow up this work. It is, however, hoped that this note will stimulate further investigations into the occurrence of *M. vertebralis* in South Australia's past—and present?

¹Howchin, W. (1923). Rep. Australas. Ass. Advmt. Sc., 16, 94-101.

²Howchin, W. (1935). Trans. R. Soc. S. Aust., 59, 68-102.

³Logan, B. W., Brown, R. G. & Quilty, R. G. (1976). 25th Inter. Geol. Cong. Excursion Guide No. 37A.

⁴McKenzie, K. G. (1962). J. Proc. R. Soc. West Aust., 45, 117-132.

⁵Chapman, F. & Parr, W. J. (1935). J. Proc. R. Soc. West. Aust., 21, 1-7.

⁶Bone, Y. (1978). B.Sc. (Hons.) thesis Univ. Adel. (unpubl.).

⁷Firman, J. B. (1966). Q. geol. Notes, geol. Surv. S. Aust., 17, 6-8.

⁸Bathurst, R. G. C. (1975). Carbonate sediments and their diagenesis. (Elsevier: New York).

⁹Loeblich, A. R. & Tappan, H. (1964). In: Moore, R. C. (Ed.), Treatise on Invertebrate Paleontology. Part C, Protista 2, Vols. 1, 2. (Geol. Soc. America & Univ. Kansas Press).

THE IDENTITY OF ORCHEZELANDIA RUBRA (COLLEMBOLA: ENTOMBRYIDAE)

BY *PENELOPE GREENSLADE*

Summary

In the course of a study of the scaleless Orchesellini of Australia, a New Zealand species, *Orchezelandia rubra* Salmon, 1937, which had been placed in the tribe, was examined and found to belong to the genus *Entomobrya* in the Entomobryini of the same family.

THE IDENTITY OF *ORCHEZELANDIA RUBRA* (COLLEMBOLA: ENTOMOBRYIDAE)

In the course of a study of the scaleless Orchesellini of Australia,¹ a New Zealand species, *Orchezelandia rubra* Salmon, 1937, which had been placed in the tribe, was examined and found to belong to the genus *Entomobrya* in the Entomobryini of the same family.

With the transfer of this species from the Orchesellini to the Entomobryini, there remain no scaleless Orchesellini species recorded from New Zealand and only one scaled species, *Heteromurus nitidus* (Templeton)². Like New Zealand the tribe is poorly represented in Australia also compared with Europe. A single tropical scaled species, *Heteromurus* (*Alloscopus*) *tetracanthus* Börner, is known from north Queensland³, and a few species of the genus *Australomurru* Stach from the southeast of Australia. The latter genus was originally described in the Isotomidae but is now known to be a member of the Orchesellini⁴.

Entomobrya rubra (Salmon) nov. comb. (Fig. 1)

Orchezelandia rubra Salmon, 1937, Trans. Roy. Soc. N.Z., 67(2): 356, plate 51a-c.

Orchesellides rubrum Bonet, 1942, Ciencia 3(2): 56.

Orchesellides rubra Salmon, 1944, Rec. Dom. Mus. 1(2): 165.

Species with five-segmented antennae, tridentate mucrones and ratio of abdominal segments III:IV of 1:3-4. These characters were figured. He therefore clearly separated *Orchezelandia* from *Orchesella* Templeton on the basis of antennal, mucronal and abdominal morphology. Although not definitely stated, it appears Salmon only had one specimen of his species and in 1941 he recorded the registration number when he published a new description of *O. rubra* with redrawn figures⁵; he also corrected the description of the mucro to "bidentate with basal spine". By so doing he removed one of the characters by which *Orchezelandia* differed from *Orchesellides*, a genus described earlier by Bonet⁶ also with five-segmented antennae, leaving only a differing ratio of abdominal segments III and IV to distinguish the two genera.

In 1942 Bonet synonymised *Orchezelandia* with *Orchesellides* stating that Salmon's description concurred absolutely with his own. He mentioned the differences in the proportions of abdomen III and IV (i.e. from 1:3-4 in *O. rubrum* to 3:4 in *Orchesellides borealis*) and stated they were "clearly of specific value". Salmon later agreed with Bonet's synonymy and published it as *Orchesellides rubra* nov. comb. in 1944.

A recent study has shown that the type and sole specimen has four-segmented antennae, although the insertion of the first antennal segment on the right side is unusually prominent on the mounted type but it is clearly without setae. In other respects the specimen agrees with Salmon's description although some of the characters cannot be seen clearly i.e. the mucrones and tip of ant. IV, because of the alignment of the specimen and of darkening of the mounting medium. The ratio of abdomen III:IV is as Salmon stated (1:3.5) and the body is covered with short ciliated setae with some macrochaetae with flexed tips which are dense on Thorax II and less dense on other segments and on the head. In all respects the specimen agrees (in those characters which can be seen) with *Entomobrya* Rondani and it is hereby transferred to this genus. Bonet's comments that *Orchesellides* is closely related to *Entomobrya* apart from the segmentation of the antennae and ratio of abdominal segments III and IV. A complete description of the species should await recollection from the type locality and revision of genus *Entomobrya* from New Zealand.

Entomobrya rubra seems nearest to *E. handschani* Stach in colour pattern, ratio of abdomen III to IV, antennal length and ratio of antennal segments and claw. The trochanteral organ, tip

Fig. 1. *Orchezelandia rubra* Holotype, a, left side of head and antennal segment I, b, right side of head and antennal segment I, c, dorsal view thorax II abdomen I-VI, d, claw III, e, dorsal view abdomen III right side showing macrochaetae.

Material examined. Holotype, *Orchesellides* (*Orchezelandia*) *rubra*, det L. F. Salmon, Type (Mind eupatal) NMNZ 3/197, Newberry, Palm Nth., in soil, 1933 (labelled by FLS).

Salmon erected a new genus of scaleless Orchesellini, *Orchezelandia* in 1937 on the basis of a

of ant. IV, bothriotricha, and labrum cannot be seen clearly on the specimen. However I have compared *E. rubra* with various species of *Entomobrya*, *Australotomurus* Stach and *Orchesella* and it is more similar to species of *Entomobrya* than to those of the other two genera both in

general appearance and in other morphological details.

This work was carried out while the author was in receipt of a grant from the Science and Industry Fund, and a French Government Scholarship.

¹Mari Mutt, J. A. & Greenslade, Penelope. In press.
²Wise, K. A. J. (1977). Bull. Auckland Inst. Mus. 11, 1-176.

³Mari Mutt, J. A. (1982). Pacif. Insects 24, 84-94.
⁴Salmon, J. T. (1941). Trans. R. Soc. N.Z. 70(4), 282-431.
⁵Bonet, F. (1930). Eos, Madrid 6, 249-273.

PENELOPE GREENSLADE, South Australian Museum, North Terrace, Adelaide, S. Aust. 5000.

ERRATA

BLACKBURN, G., ALLISON, G. B. and LEANEY, F. W. J. (1982). Further evidence on the age of tuff at Mt. Gambier, South Australia. *Trans. R. Soc. S. Aust.* 106(4) 163-167.
The isotope data reported were slightly in error. The correct data are given in the Table.

TABLE 1. Details of charcoal samples and isotope measurements.

Sample No.	CSIRO No.(s)	Volcanic Ash Zone	Distance from Blue Lake (km)	Depth of sample below surface (m)	Thickness of tuff layer(s) (m)	Depth of sample below volc. affected material (m)	$\delta^{13}\text{C}$ ($\%$ rel to PDB)	Acid pre-treatment	^{14}C Age Alkali pre-treatment (± 1 sd.)
1	CS44	Outer (B)	5E	0.6	—	—	—	470 \pm 210	n.d.
2	CS35	Inner (A)	4SSE	0.6	0.03	0.3	-24.3	7240 \pm 250	7300 \pm 250
3	CS34	Outer	5NNE	0.45	—	0.15	-25.5	7670 \pm 240	7710 \pm 150
4	CS45	Outer	8NNE	0.20	—	—	—	860 \pm 210	n.d.
5	CS46	Outer	4N	0.6	—	—	—	3600 \pm 220	n.d.
6	—	Outer	4N	0.5	—	0.02	-24.2	n.d.	470 \pm 200
7	CS43	Outer	5SSW	0.5	—	0.04	-24.4	5680 \pm 230	5550 \pm 245
8	—	Inner	2.5N	1.1	0.45	0.10	-25.5	n.d.	4670 \pm 240
9	CS40	Inner	2.5N	1.1	0.3	0.15	—	4060 \pm 285	n.d.
10	CS42	Inner	2SE	1.6	0.6	0.10	-24.8	4450 \pm 230	3380 \pm 200
11	CS41	Outer	4NNE	0.9	0.04	0.23	-25.1	8190 \pm 260	6700 \pm 240

LIFE HISTORY OF THE SCIRON SKIPPER TRAPEZITES SCIRON EREMICOLA BURNS (LEPIDOPTERA: HESPERIIDAE)

BY R. H. FISHER

Summary

The skipper butterfly *Trapezites sciron eremicola* inhabits open heathland in mallee areas from Eyre Peninsula to western Victoria. The nominate subspecies, *T. s. sciron* Waterhouse & Lyell, was described from southwestern Australia. The life history and early stages of ssp *eremicola* are described here from material collected in Ngarkat Conservation Park (35°40'S, 140°30'E), South Australia.

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Larval food plant: *Lomandra glauca* (R. Br.) Ewart (Liliaceae). In the butterfly's habitat the plant occurs predominantly on the northern aspect of the crests of ridges and sandhills (Fig. 1).



Fig. 1. Habitat of *T. sciron eremicola*, Billiatt Conservation Park, South Australia. Larval food plants in left foreground.

Description of immature stages. Egg (Fig. 2A): diameter 1 mm; almost hemispherical with 19–22 distinct vertical ridges intersected by numerous obscure lateral lines; pale cream when newly laid but developing a broad brown lateral band after several days.

First instar larva (Fig. 2B): length 3 mm; body white with a few long posterior setae, prothoracic

plate a dark brown transverse band; head shining black with a few short setae.

Mature larva (Fig. 2C, D): length 20 mm; body white with obscure grey markings and a distinct grey dorsal line, spiracles black, prothoracic plate with a black posterior margin, anal plate with numerous swollen white setae arising from black bases and with four short, black-tipped posterior setae; head capsule rugose and with short swollen setae, dark brown with scattered paler markings; frons with paired longitudinal pale brown bands diverging ventrally.

Pupa (Fig. 2E, F): length 17 mm; cylindrical, abdomen tapering sharply and terminating in a red-brown cremaster with a cluster of hooked setae; pale brown with darker markings, particularly on the head and thorax, body surface except wing cases with groups of branched white setae. The setae resemble those described on the pupae of *Trapezites heteromaculata* Meyrick & Lower¹. **Biology:** Eggs are laid singly on the leaves of the food plant. The young larva emerges from the egg after about five days and makes a simple shelter by joining the bases of a few fresh leaves of the food plant with silk. When more mature it constructs a silken shelter incorporating debris, dried leaves and sand which is attached to residual leaves where they arise from the basal sheaths of the food plant (Fig. 2G, H). Pupation occurs in late August within the shelter, which is open at the top and well-concealed. Adults appear from spring to early summer and both sexes exhibit hill-topping behaviour in open areas on the crests of sandhills.

I thank the Wildlife Conservation Fund for financial assistance in field work, the National Parks & Wildlife Service for permission to collect material in Ngarkat Conservation Park, D. F. Crosby and A. E. Mitchell for the use of vehicles and J. S. Womersley for botanical identification.

¹Atkins, A. F. & Miller, C. G. (1977). Aust. ent. Mag. 3, 104–106.

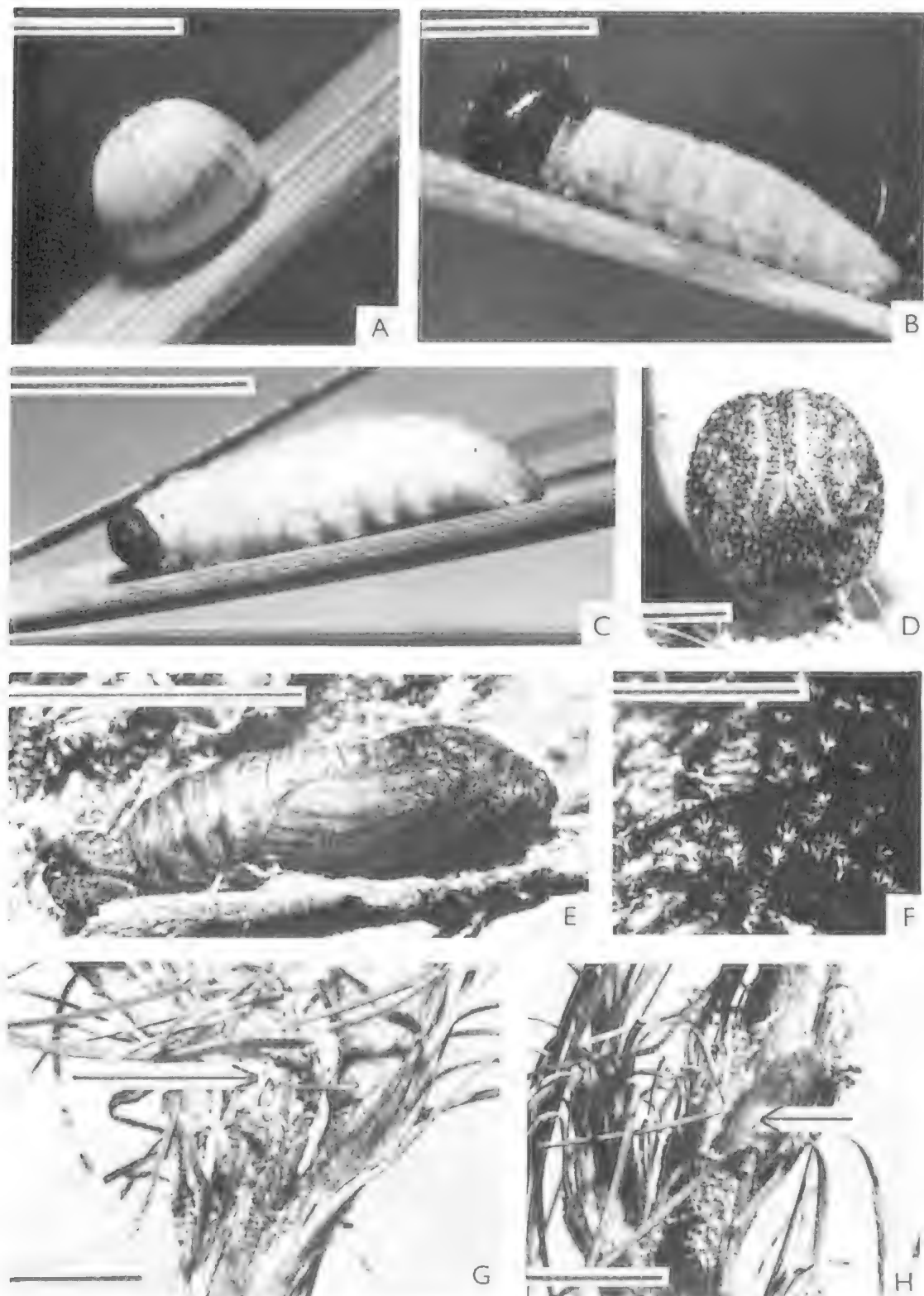


Fig. 2. *T. sciron eremicicola*. A egg. B first instar larva. C mature larva. D head of mature larva. E pupa with larval head cast at left. F branched setae on pupa. G, H larval or pupal shelters, H partly opened to show pupa. Bar scales A, B, D, F 1 mm; C, E, G, H 1 cm.

FURTHER ADDITIONS TO THE MARINE FISH FAUNA OF SOUTH AUSTRALIA

BY C. J. M. GLOVER

Summary

Six species of fish are newly recorded for South Australia, most on the basis of single specimens. One species, *Idiacanthus niger*, represents the first record of the family Idiacanthidae in the region. A seventh species (*Metavelifer multiradiatus*) and family (Veliferidae), are reported from South Australian waters for the first time. Four of the species were included in a checklist for the south east of the State but without further details. All species reported here have been recorded elsewhere in temperate waters around Australia; some also in tropical waters. All occur beyond Australia.

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Some of the species are acknowledged wide-ranging oceanic forms (*Hexanchus griseus*, *Gasterochisma melampus*, *Makaira indica* and *Lagocephalus lagocephalus*), but lack of supplementary records does not indicate permanent extensions of distribution into the South Australian region. As with some earlier records²⁻⁷ these latter records probably represent vagrants.

The discovery of *H. griseus*, *I. niger* and *Cyttus novaezelandiae* reflect recent increased deepwater commercial fishing off South East South Australia.

Family Hexanchidae. *Hexanchus griseus* (Bonaterre, 1788).

A specimen (Fig. 1) was captured on a long-line, set at 329 m depth, on a flat "muddy" sea bed, about 46 km southwest of Beachport, S. Aust. (approx. 37°43'S, 139°35'E), on 17.vii.1982, by R. Morgan.

H. griseus has been recorded in Australia off Tasmania, Victoria and New South Wales, between Port Fairy (Vic.) and Norah Head



Fig. 1. *Hexanchus griseus*. SAM F4740. TL 1450 mm.

(N.S.W.)⁸, unpubl. recs. It is found in tropical and temperate waters worldwide.⁹

Family Idiacanthidae. *Idiacanthus niger* Regan, 1914.

One specimen (Fig. 2) was trawled, at 549 m depth, about 47 km southwest of Cape Buffon, S. Aust. (approx. 37°52'S, 139°43'E), in iv.1981, by J. Sealey.

I. niger has been recorded in Australia in deep water off western Vic. and N.S.W. (unpubl. recs.), and is also known off New Zealand, Chile and South Africa^{10,11}.

Family Veliferidae. *Metavelifer multiradiatus* (Regan, 1907).

A specimen (Fig. 3) was trawled, at 40 m depth, 4 km southeast of Evans Island, near Ceduna, S. Aust. (approx. 32°24'S, 133°31'E), on 3.xi.1983, by A. Olsen.

M. multiradiatus has been reported previously from W.A., N.S.W.¹², and "the Great Australian Bight"¹³. It has been recorded also (but not reported) in the Great Australian Bight specifically off the S. Aust. coast (unpubl. recs.). Beyond Australia, the nominal *Velifer multispinosus* Smith, 1951, from southeast Africa, is a synonym of *M. multiradiatus*¹⁴.



Fig. 2. *Idiacanthus niger*. SAM F4757. TL 400 mm.



Fig. 3. *Metavelifer multiradiatus*. SAM F4746. TL 109 mm.

Family Zeidae. *Cyttus novaezelandiae* (Arthur, 1885).

Five specimens (Fig. 4) were trawled, at 549 m depth, about 47 km southwest of Cape Buffon, S. Aust. (approx. 37°52'S, 139°43'E), in iv.1981, by J. Sealey.

C. novaezelandiae has been recorded in Australia from Tasmania, Vic. and N.S.W.⁸ It is also known from New Zealand¹⁰.

Family Scombridae. *Gasterochisma melampus* Richardson, 1845.

A specimen (Fig. 5) was trolled, about 23 km west-northwest of Port MacDonnell, S. Aust. (approx. 38°03'S, 140°26'E), on 7.vi.1982, by I. J. Carrison.

G. melampus has been recorded in Australia from off Tas., Vic., N.S.W. and Qld.⁸ It is also known from other temperate waters of the southern hemisphere, e.g. New Zealand, Argentina and South Africa^{10,11}.

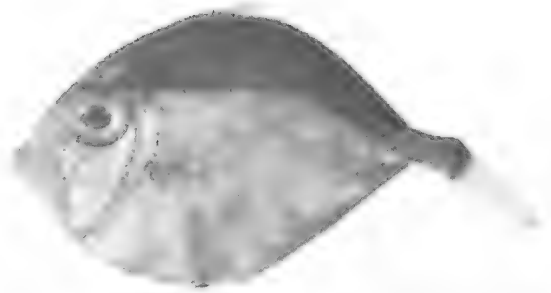


Fig. 4. *Cyttus novaezelandiae*. SAM F4745. TL (largest specimen) 195 mm.

Family Istiophoridae. *Makaira indica* (Cuvier, 1831).

A dead specimen (Fig. 6) was found floating at the surface near the grain wharf at Thevenard, S. Aust. (pprox. 32°09'S, 133°39'E), on 15.iv.1983, by A. E. & D. J. Holder. Fisheries officer J. N. R. Smith took the photograph (Fig. 6) and measurements. A. E. Holder of Thevenard kept only the head.

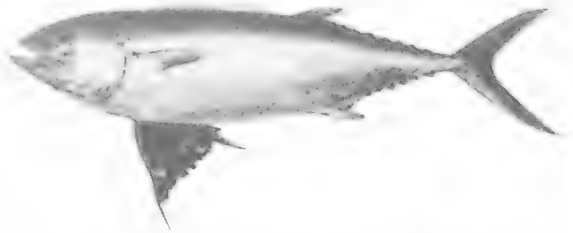


Fig. 5. *Gasterochisma melampus*. SAM F4759. TL 970 mm.



Fig. 6. *Makaira indica*. TL 3820 mm.

M. indica has been recorded in Australia from W.A. (Shark Bay and off Albany) and N.S.W. (Port Stephens) (unpubl. recs.). It ranges widely in circumglobal temperate and tropical waters¹⁵.

Family Tetraodontidae. *Lagocephalus lagocephalus* (Linnaeus, 1758).

A dead specimen (Fig. 7) was found on the beach near the jetty at Port MacDonnell, S. Aust. (approx. 38°03'S, 140°42'E), on 9.v.1983, by P. Cawthorne.

L. lagocephalus has been recorded in Australia from Tasmania⁸. This species is well known in the Atlantic, Indian and Pacific Oceans¹⁶.

Those persons mentioned (all professional fishermen) are thanked for collecting and donating the specimens to the South Australian Museum. G. Bond (Arena Sports Store, Mt Gambier) and J. N. R. Smith (S.A. Dept. of Fisheries) are thanked for assistance with the *L. lagocephalus* and *M. indica* specimens respectively.



Fig. 7. *Lagocephalus lagocephalus*. SAM F4733. TL 520 mm.

¹Glover, C. J. M. (1983) Freshwater and marine fishes. In Tyler, M. J., Twidale, C. R., Ling, J. K. & Holmes, J. W. (Eds) "Natural History of the South East", pp. 157-167. (Royal Society of South Australia: Adelaide.)

²Glover, C. J. M. (1966). Rec. S. Aust. Mus. 15 (2), 353-355.

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⁴Glover, C. J. M. (1976). *Ibid.* 50(4), 69-72.

⁵Glover, C. J. M. & Branden, K. L. (1978). *Ibid.* 52(4), 55-60.

⁶Glover, C. J. M. & Branden, K. L. (1983). Trans. R. Soc. S. Aust. 107(2), 134-136.

⁷Kailola, P. J. & Jones, G. K. (1981). *Ibid.* 105 (4), 211-212.

⁸Last, P. R., Scott, E. O. G. & Talbot, F. H. (1983). Fishes of Tasmania. (Tasmanian Fisheries Development Authority: Hobart.)

⁹Bass, A. J., D'Aubrey, J. D. & Kistnasamy, N. (1975). Invest. Rept. No. 43, Oceanographic Resch. Inst., South African Assoc. Mar. Biol. Resch.

¹⁰Whitley, G. P. (1968). Aust. Zool. 15(1), 1-102.

¹¹Smith, J. L. B. (1950). The Sea Fishes of Southern Africa. (Central News Agency Ltd: South Africa.)

¹²Munro, I. S. R. (1957). Fisheries Newsl. 16(9), 15-18.

¹³Whitley, G. P. (1962). Marine Fishes of Australia, Volume 1. (Jacaranda Press: Brisbane.)

¹⁴Walters, V. (1960). Copeia, 3: 245-247.

¹⁵Nakamura, I. (1975). NOAA Tech. Rept. NMFS SSRF-675, part 3, 17-27.

¹⁶Fowler, H. W. (1928). Memoirs Bernice P. Bishop Mus., X, i-iii, 1-540, pls. I-XLIX.

A RE-EXAMINATION OF TAENI MASTERSII KREEFT, 1871 AND TAENIA FIMBRIATA KREEFT, 1871

BY I. BEVERIDGE

Summary

In 1871, G. Krefft published brief and inadequate accounts of a number of species of cestode collected from Australian mammals and birds. None of the species is recognisable by contemporary standards. Johnston redescribed and rehabilitated, from Krefft's type specimens, most of the cestodes from birds. He listed *Taenia mastersii* Krefft, 1871 and *T. fimbriata* Krefft, 1871, both from wallabies, but did not redescribe them or comment on their affinities. Beveridge, in revising the Anoplocephalidae of Australian marsupials, pointed out that Krefft's names, *Taenia mastersii* and *T. fimbriata*, could take priority over newer names currently in use if the species could be rehabilitated.

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The writer has recently located type material of both *T. mastersii* and *T. fimbriata* in the Australian Museum (G11160 and G11156). The type specimens of *T. mastersii* (G11160) consist of 4 complete specimens including the scoleces. In an intact scolex examined, the rostellar hooks were arranged in a six-lobed circle with hook lengths between 30–40 μm long. These two features, namely the shape of the ring of rostellar hooks and their lengths, are characteristic of *C. thylogale* and clearly identify *T. mastersii* and *C.*

thylogale, supporting earlier observations on the morphology of the mature proglottides³. *C. thylogale* therefore becomes a synonym of *T. mastersii* as *Calostaurus mastersii* (Krefft, 1871) comb. nov. *C. mastersii* was originally collected from an unknown species of wallaby in Queensland. All recent collections are from *T. billardieri* in Tasmania⁴.

The type specimen of *T. fimbriata* in the Australian Museum (G11156) has external features similar to *P. zschokkei* with a broad, prominently fimbriated velum and paired genital pores. Serial histological sections of a fragment of the type specimen also reveal internal features similar to *P. zschokkei*, namely paired genitalia, a single uterus, heavily armed and coiled cirri and large seminal receptacles. However, even the youngest proglottides of the type specimen are nearly gravid, with the uteri obliterating most of the sexual organs and consequently the distinguishing characters of the mature proglottis (distribution and number of testes) cannot be determined. *P. zschokkei* and *P. villosa* (Lewis, 1914) are the only known species of the genus with fimbriated vela and a single uterus. They can be distinguished from one another by the number of testes per proglottis, by the length of the velum and by the pattern of development of the genitalia³. *T. fimbriata* has a velum similar to that of *P. zschokkei*, but assessment of this character is somewhat subjective and neither the number of testes per proglottis, nor the pattern of development of the genitalia can be determined from the type fragment of *T. fimbriata*. Therefore, although *T. fimbriata* and *P. zschokkei* are possibly the same species, their identity cannot be demonstrated beyond reasonable doubt. Since the host and collection locality of the type of *T. fimbriata* are not known, and thus further collections of the parasite cannot be made, *T. fimbriata* must continue to be regarded as a *nomen nudum*.

Thanks are due to P. Hutchings for the loan of type specimens from the Australian Museum, Sydney.

¹Krefft, G. (1871). Trans. Entomol. Soc. N.S.W. 2, 206–232.

²Johnston, T. H. (1912). Rec. Aus. Mus. 9, 1–35.

³Beveridge, I. (1976). Aust. J. Zool. Suppl. Ser. No. 44, pp. 110.

⁴Beveridge, I. (1975). J. Helminthol. 49, 129–136.

⁵Beveridge, I. (1981). Trans. R. Soc. S. Aust. 105, 139–147.

THE IDENTITY OF RED-BELLIED BLACK SNAKES ON KANGAROO ISLAND

BY TERRY D. SCHWANER

Summary

The red-bellied black snake, *Pseudechis porphyriacus*, although not reported previously from Kangaroo Island, was listed as occurring on the island based on specimens in the South Australian Museum. The authors stated, "This snake, like the Black Tiger, is jet black above and grows to about 1.5 m, but is distinguishable by its whitish belly which is usually tinged along its lateral margins with pink or crimson ... On the island it has been seen in coastal heath on the south side, but it is not common and its usual habitat there is in doubt." Two recent observations have led me to conclude that *Pseudechis porphyriacus* is not a member of the herpetofauna of Kangaroo Island.

THE IDENTITY OF RED-BELLIED BLACK SNAKES ON KANGAROO ISLAND

The red-bellied black snake, *Pseudechis porphyriacus*, although not reported previously from Kangaroo Island,^{1,2,3} was listed as occurring on the island based on specimens in the South Australian Museum.⁴ The authors stated, "This snake, like the Black Tiger, is jet black above and grows to about 1.5 m, but is distinguishable by its whitish belly which is usually tinged along its lateral margins with pink or crimson . . . On the island it has been seen in coastal heath on the south side, but it is not common and its usual habitat there is in doubt."⁴ Two recent observations have led me to conclude that *Pseudechis porphyriacus* is not a member of the herpetofauna of Kangaroo Island.

The only specimen identified as *Pseudechis porphyriacus* in the South Australian Museum Collection (SAM R4366, Kelly Hill Caves, K.I.) is reidentified as a melanistic tiger snake of the *Notechis scutatus/ater* complex. No specimens of *Pseudechis porphyriacus* from K.I. have been located in the collections of the Australian Museum, Western Australian Museum, National Museum of Victoria, Museums & Art Galleries of the Northern Territory, Australian National Wildlife Collection or the Queensland Museum (R. Sadler, G. Storr, J. Coventry, P. Horner, J. Wombey and J. Covacevich pers. comm.).

Recent studies on variation in colour pattern of tiger snakes (*Notechis scutatus/ater* complex) of Kangaroo Island involved the collection of fresh, roadkilled specimens by rangers of the South Australian National Parks and Wildlife Service and local residents. Among these specimens were tiger snakes with reddish bellies (Fig. 1). Red-bellied tiger snakes are colour forms of the highly variable Kangaroo Island populations (Schwaner, in prep.). However, these are easily distinguished from *Pseudechis porphyriacus* by the shape of their subcaudal scales, in which most scales are entire, undivided plates (divided and

paired in *P. porphyriacus*). Localities for two specimens with reddish bellies are both in the Hundreds of Haines district in South Central K.I., although similarly coloured individuals could be found elsewhere on the island.

Thus red-bellied black snakes on Kangaroo Island are not *Pseudechis porphyriacus* but red-bellied, melanistic tiger snakes (*Notechis scutatus/ater* complex).

I thank T. Dennis, M. McKelvey, H. Stitchell and J. Watkins for collecting the specimens. Roman Ruehle took the photograph in Fig. 1, and Lila Schwaner typed the manuscript.



Fig. 1. Ventral pattern of a red-bellied, melanistic tiger snake (*Notechis scutatus/ater* complex) from Kangaroo Island. The specimen (SAM R24987) is an adult female (SVL = 1115 mm) collected on a road at Ayliffe Hill (Hund. of Haines) by M. McKelvey on 3.xi.83. Light areas of the belly are Spinel Pink (Colour 108C).⁵ Note the undivided subcaudal scales.

¹Waite, E. R. (1925). Rec. S. Aust. Mus. 3, 17-32.

²Waite, E. R. (1927). Trans. R. Soc. S. Aust. 51, 326-329.

³Waite, E. R. (1929) "The Reptiles and Amphibians of South Australia." (Government Printer: Adelaide.)

⁴Houston, T. F. & Tyler, M. J. (1979) In M. J. Tyler, C. R. Twidale, & J. K. Ling, Eds. "Natural History of Kangaroo Island". (Roy. Soc. S. Aust.: Adelaide).

⁵Smith, F. B. (1981). Naturalist's color guide. Part III. (Amer. Mus. Nat. Hist.: New York.)

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THE EFFECTS OF SALINITY ON THE DISTRIBUTION OF AMPHIPODS IN THE COORONG, SOUTH AUSTRALIA, IN RELATION TO THEIR SALINITY TOLERANCE

BY M. I. KANGAS & M. C. GEDDES

Summary

The tolerance of *Melia zeylanica* and *Paracorophium* sp. to a range of salinity and temperature combinations was investigated by LD₅₀ analysis and response surface analysis. At the optimum temperature of 18-20°C, the salinity tolerance of both species was from 1 to 62‰; at high and low temperatures, tolerance to high salinity was reduced. *Melita zeylanica*, *Paracorophium* sp. and *Megamphopus* sp. were common in the Coorong, but all species generally were restricted to salinities below 53‰. No deleterious effects of salinity on the reproductive condition of populations were identified.

THE EFFECTS OF SALINITY ON THE DISTRIBUTION OF AMPHIPODS IN THE COORONG, SOUTH AUSTRALIA, IN RELATION TO THEIR SALINITY TOLERANCE

by M. I. KANGAS & M. C. GEDDES*

Summary

KANGAS, M. I. & GEDDES, M. C. (1984) The effects of salinity on the distribution of amphipods in the Coorong, South Australia, in relation to their salinity tolerance. *Trans. R. Soc. S. Aust.* **108**(3), 139-145, 13 December, 1984.

The tolerance of *Melita zeylanica* and *Paracorophium* sp. to a range of salinity and temperature combinations was investigated by LD_{50} analysis and response surface analysis. At the optimum temperature of 18–20°C, the salinity tolerance of both species was from 1 to 62‰; at high and low temperatures, tolerance to high salinity was reduced. *Melita zeylanica*, *Paracorophium* sp. and *Megamphopus* sp. were common in the Coorong, but all species generally were restricted to salinities below 53‰. No deleterious effects of salinity on the reproductive condition of populations were identified.

KEY WORDS: *Melita zeylanica*, *Paracorophium*, *Megamphopus*, salinity tolerance, amphipods, Coorong, South Australia.

Introduction

Most investigations of the salinity tolerance of estuarine and coastal marine amphipods have considered tolerance to dilute conditions (Vlasblom & Bolier 1971; Dorgelo 1974, 1976; Ritz 1980). Few studies have been made on tolerance of amphipods to concentrations greater than seawater (McLusky 1967; Marsden 1980), although amphipods are often important in hypermarine systems (Hedgpeth 1967). In the present study the salinity tolerance of *M. zeylanica* and *Paracorophium* at various temperatures were examined in the laboratory and the results related to the field distribution of the amphipod species in the Coorong lagoons. In the field study the relative abundance and reproductive status of the amphipod species are investigated to look for possible sublethal effects of salinity and temperature on amphipod populations.

The Coorong is a coastal lagoon system situated in the south east of South Australia (Fig. 1). The Coorong waters show a marked longitudinal salinity gradient which varies in direction and intensity seasonally and from year to year (Noye 1975). In 1982, the Coorong lagoons were hypersaline (Geddes & Butler, 1984), and this provided the opportunity to investigate the distribution of organisms along a hypermarine salinity gradient. Amphipods form a major part of the macrobenthic fauna and this study investigates the distribution and salinity tolerance of three common species *Melita zeylanica* Stebbing (Melitidae), *Paracorophium* sp. (Corophiidae) and *Megamphopus* sp. (Isaeidae). *Melita zeylanica* is a cosmopolitan species, commonly found in

estuarine systems (Croker 1971; Barnard 1972; Griffiths 1973; Krishnan & John 1974, 1975; Bolt 1975) and has been recorded in Australia from the Peel-Inlet (Potter *et al.* 1981) and Lucky Bay, Western Australia (Barnard 1972), from the Tuggerah Lakes, New South Wales (Collett *et al.* 1981), and from the Gippsland Lakes, Victoria (Poore 1982). The other two amphipods are

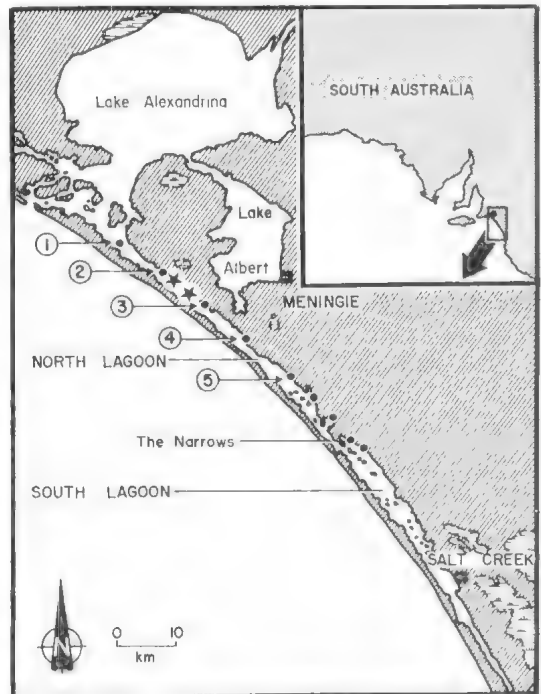


Fig. 1. The Coorong lagoons showing sampling localities (•) and sites where populations of *M. zeylanica* and *Paracorophium* sp. were collected for salinity tolerance experiments (*).

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undescribed. The genus *Paracorophium* is endemic to the Southern hemisphere and found in Australia, New Zealand and South America (Barnard & Karaman 1983). *Paracorophium* sp. differs from *P. excavatum* Chilton, the only described species known from Australia, in the structure of the third uropod and the number of setae on gnathopods 1 and 2 of the male. Very small numbers of a second undescribed species of *Paracorophium* were also collected. Neither species is similar to known *Paracorophium* species (Karaman 1979). No species of *Megamphopus* have been described from Australia (M. Drummond pers. comm.) but species have been found in abundance in the Tuggerah Lakes, N.S.W. (Collett *et al.* 1981) and the Gippsland Lakes in Victoria (M. Drummond, pers. comm.). Reference material of the species considered in this paper has been placed in the South Australian Museum, Adelaide (SAM C3924-C3927).

Materials and Methods

(i) Salinity Tolerance

Amphipods were collected in March, April and June 1982 from two localities (Fig. 1) at salinities of 51.3, 41.9 and 44‰ respectively.

Salinity tolerance was determined at five temperatures for hypersaline conditions (5.5, 14.4, 18.5, 26, 32.5°C for *M. zeylanica* and 6, 14.4, 19.5, 26, 30.5°C, for *Paracorophium* sp.) and three temperatures for dilute conditions (14, 18, 25.4°C for *M. zeylanica* 14.4, 19.5, 27.5°C for *Paracorophium* sp.). Amphipods were acclimated to test temperatures in 35‰ (seawater) for two days prior to experimentation.

9–12 amphipods were directly transferred to five salinity dilutions (0.1–10.5‰) and ten hypersaline media (38.5–73.9‰). Dilute media were prepared by mixing seawater and distilled water; hypermarine media were mixtures of seawater and Coorong water. Conductivities (K_{25}) were measured with a Radiometer CDM2e Conductivity Meter and total dissolved solids (TDS) calculated by a regression provided in Williams (1966). This regression was developed for saline lake waters but comparison of dried TDS for samples from the Coorong with values calculated from conductivity via the Williams equation showed very close agreement (Geddes & Butler, 1984). This is to be expected considering the similar nature of ionic dominance in Coorong water and that of Australian salt lakes (Williams & Buckney 1976). The TDS values were used as a measure of salinity.

At all salinity-temperature combinations, adult individuals were used without regard to sex.

Gentle aeration and a light/dark regime of 12 hour: 12 hour was maintained but no food was added. Fine debris and filamentous algae was supplied to *Paracorophium* sp. to enable it to construct tubes (considerable mortality was experienced when this tube dwelling species was kept in clear water). The number of animals surviving were counted at 6 and 24 hours and every 24 hours thereafter for 96 hours. Following Ritz (1980), death was taken as a cessation of pleopodal rhythmic beating motor response to tactile stimulation.

Data were analysed in two ways: determining LD_{50} values and fitting response surfaces to survival data. For LD_{50} determination, the dose and response (% survival) values were transformed to log dose and logits (Hewlett & Plackett 1979) and regression equations calculated with the form $Y = a + bX$ where Y is logit + 10. This form allows symmetrical confidence limits to be placed on LD_{50} values.

The response surfaces were fitted according to a BMDP program Stepwise Logistic Regression (PLR) accessed via the Cyber 173 computer. The PLR estimates the vector of parameters (β_i) for the linear logistic model $E(s/n) = e^{\beta X} / 1 + e^{\beta X}$ where s is the sum of the binary dependent variable (dead, alive) and X represents the independent variables (salinity, temperature). The parameter β_i may be expanded to a quadratic $\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1^2 + \beta_4 X_2^2 + \beta_5 X_1 X_2$ where X_1 is the temperature, X_2 is the salinity, β_0 is a constant, β_1 is the linear effect of temperature, β_2 is the linear effect of salinity, β_3 is the quadratic effect of temperature, β_4 is the quadratic effect of salinity and β_5 is the interaction effect between temperature and salinity. Contour lines for specified percent survival were then plotted.

(ii) Field Observations

A series of offshore stations (Fig. 1) were sampled in the North Lagoon of the Coorong at approximately monthly intervals from January 1982–March 1983. The northern end of the South Lagoon was sampled in August 1982 (Fig. 1). At each station, surface temperatures and water samples were taken. Amphipods were collected by towing a trawl net (160 μ m) through algal beds for 5–10 minutes. The samples were returned to the laboratory, sorted, preserved in 10% formalin and identified. One hundred randomly selected individuals were identified to record species composition and relative abundance; within each species, sex ratio, female reproductive condition, and egg number were noted.

Results

(i) Salinity Tolerance

Tables 1 and 2 summarise results found through logit analysis for *M. zeylanica* and *Paracorophium* sp. respectively. The lower LD₅₀ value for *M. zeylanica* and *Paracorophium* sp. is 1.0‰ and the upper LD₅₀ value for *M. zeylanica* is 62‰ and for *Paracorophium* sp. is 60.5‰, indicating a wide tolerance range for each species. Due to the wide confidence limits, the respective values of LD₅₀ at each temperature trial overlap with the preceding and following values. General trends are that highest LD₅₀ values occur at medial temperatures while they decrease at both lower and higher temperatures. For *M. zeylanica* at 5.5°C the LD₅₀ value is 52‰ and at 32.5°C is reduced to 49‰. For *Paracorophium* sp. the LD₅₀ value is 59‰ at 6.0°C and 48‰ at 30.5°C.

The contour patterns for salinity-temperature combinations are shown in Fig. 2. Both species

show wide temperature and salinity tolerance with greater than 90% survival over most of the experimental range. The central region in the contour pattern provides an estimate of optimum conditions (Aldridge 1972). The close spacing of the contours indicates relatively low variability of response in the experimental animals.

Temperature and salinity values and the relative abundance of species at stations 1, 2, 3, 4 and 5 (Stations 1, 3, 5, 7 and 9 in Geddes & Butler, 1984) during the period December 1981–March 1983 are shown in Fig. 3. Low salinities in Dec. 1981, presumably the result of freshwater influx from Lake Alexandrina, were followed by an increase in salinity during the summer months, a lowering during April–June and an increase the following summer. At stations 4 and 5 highest recorded salinities were 68‰ and 82‰ in January 1983. Surface temperature reached 27°C in summer and the minimum was 11°C in June.

TABLE 1. Relationship between $\logit + 10$ of % mortality (x) and $\ln K_{10}$ (y) and the calculated LD₅₀ values for *M. zeylanica* for high and low salinities and at various temperatures

Temp.	Regression Equation	r ²	LD ₅₀ ± 95% confidence limits (K ₂₅)	LD ₅₀ ± 95% confidence limits (Salinity: TDS)
5.5c	$\ln y = 3.896 + 0.036 x$	0.744	70.18 ± 14.92	51.9 ± 9.0
14.4c	$\ln y = 4.382 + 0.006 x$	0.010	71.68 ± 75.60	53.3 ± 56.9
18.5c	$\ln y = 4.111 + 0.025 x$	0.731	78.49 ± 16.29	61.8 ± 9.9
26.0c	$\ln y = 4.168 + 0.017 x$	0.191	76.72 ± 35.19	58.0 ± 23.0
32.5c	$\ln y = 3.81 + 0.04 x$	0.682	67.47 ± 18.73	49.4 ± 11.5
14.0d	$\ln y = 4.57 - 0.376 x$	0.947	2.25 ± 6.03	1.3 ± 3.5
18.0d	$\ln y = 3.83 - 0.329 x$	0.925	1.72 ± 6.83	1.0 ± 4.0
26.0d	$\ln y = 4.771 - 0.356 x$	0.834	3.36 ± 28.90	1.9 ± 18.4

c—intermediate and concentrated media.

d—dilute media.

TABLE 2. Relationship between $\logit + 10$ of % mortality (x) and $\ln K_{10}$ (y) and the calculated LD₅₀ values for *Paracorophium* sp. for high and low salinities and at various temperatures

Temp.	Regression Equation	r ²	LD ₅₀ ± 95% confidence limits (K ₁₀)	LD ₅₀ ± 95% confidence limits (Salinity: TDS)
6.0c	$\ln y = 3.867 + 0.049 x$	0.518	78.33 ± 25.81	59.5 ± 16.3
14.4c	$\ln y = 4.092 + 0.028 x$	0.597	79.44 ± 24.6	60.5 ± 15.4
19.5c	$\ln y = 4.002 + 0.031 x$	0.610	79.21 ± 23.45	60.3 ± 14.6
26.0c	$\ln y = 3.794 + 0.049 x$	0.614	72.61 ± 18.26	54.1 ± 11.2
30.5	$\ln y = 3.749 + 0.044 x$	0.789	66.07 ± 15.39	48.2 ± 9.3
15.0d	$\ln y = 4.101 - 0.476 x$	0.536	0.52 ± 33.17	0.3 ± 21.5
18.0d	$\ln y = 4.136 - 0.476 x$	0.576	0.54 ± 30.56	0.3 ± 19.6
27.5d	$\ln y = 4.961 - 0.442 x$	0.640	1.72 ± 26.82	1.0 ± 17.0

c—intermediate and concentrated media.

d—dilute media.

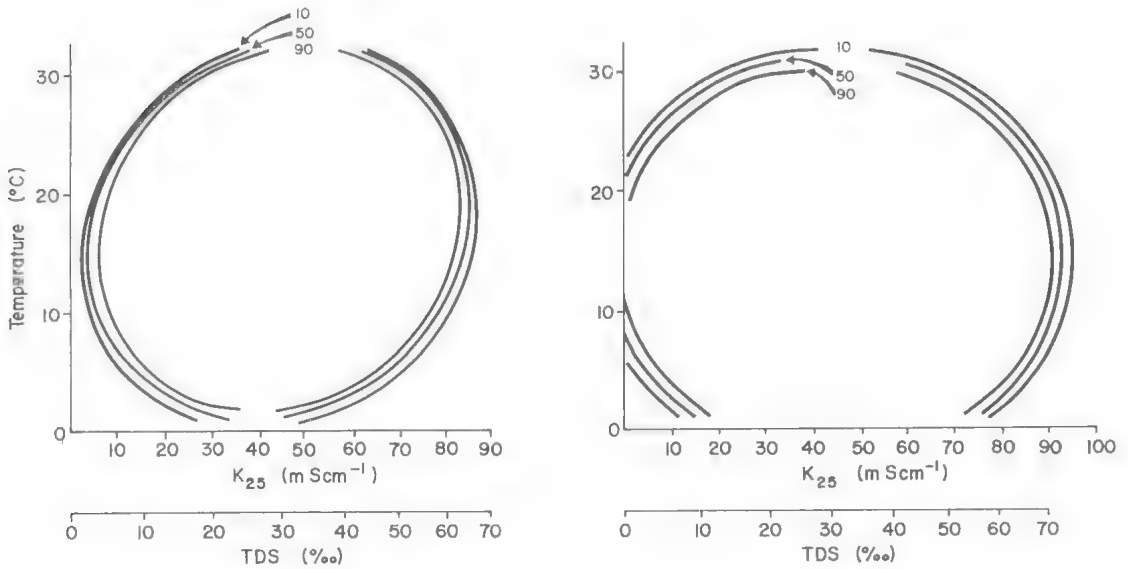


Fig. 2. Estimation of percent survival based on a fitted response surface to observed mortality at 96 hr. under 65 conditions of temperature and salinity.

(a) *M. zeylanica* ($e^{1/1} + e^{-1} = -4.695 + .237s \pm .551t - .003s^2 - .019t^2 - .391ts$).

(b) *Paracorophium* sp. ($e^{1/1} + e^{-1} = -2.183 + .18s - .002s^2 - .016t^2$).

M. zeylanica, *Paracorophium* and *Megamphopus* sp. were found at stations 1, 2 and 3 throughout the study period. *Paracorophium* sp. and *Megamphopus* sp. occurred at station 4 in Jan. 1982 at a salinity of 60‰, but seem to have succumbed to the increasing salinities in the following months. In Nov. and Dec. 1982 *Paracorophium* sp. reappeared after a period of lowered salinities. *Melita zeylanica* was collected from station 4 in May when salinity dropped to 51‰. *Paracorophium* sp. was the only species found at station 5 with 5 individuals collected in June. In the South Lagoon salinities were above 80‰ and no amphipods were found.

All three species maintained large populations at stations 1, 2 and 3 throughout the study period. *Paracorophium* sp. generally had the greatest relative abundance and seasonal fluctuations in the abundance of *Paracorophium* sp. were small. *M. zeylanica* occurred in higher numbers from March–June with a lowering of numbers from Feb.–April 1982 but their abundance was high from June–Nov.

Table 3 documents the effects of salinity and season on the reproductive condition of females; it compares the mean percent ovigerous females and the mean egg number per ovigerous female for the different stations in "summer" (Jan.–April 1982 and Nov. 1982–March 1983) and "winter" (June–Oct. 1982).

All three species breed throughout the year with

similar numbers of ovigerous females being present during the summer and winter months. The percent ovigerous females does not show a consistent change between stations, although a substantial decrease occurs at station 4 for *Paracorophium* sp. The mean number of eggs per ovigerous female for *M. zeylanica* was similar between stations and seasons except for a low egg number at station 3 in summer. For *Paracorophium* sp. and *Megamphopus* sp. there were often significant differences in egg number between stations, with highest egg number generally recorded at station 2.

Discussion

A longitudinal gradient of increasing salinity persisted in the Coorong throughout 1982 with hypersaline conditions being maintained over most regions. In years of high River Murray flow the North Lagoon of the Coorong experiences marked lowering of salinity levels (Noye 1975) and so to persist in this region the fauna must be able to tolerate both estuarine and hypermarine conditions. This may limit species richness. In the event, amphipods in the Coorong form a simple assemblage with only three common species. In comparison, many estuaries have a much larger assemblage of amphipods (Gable & Croker 1978; Collet *et al.* 1981). Although *Melita zeylanica*, *Paracorophium* and *Megamphopus* are found in

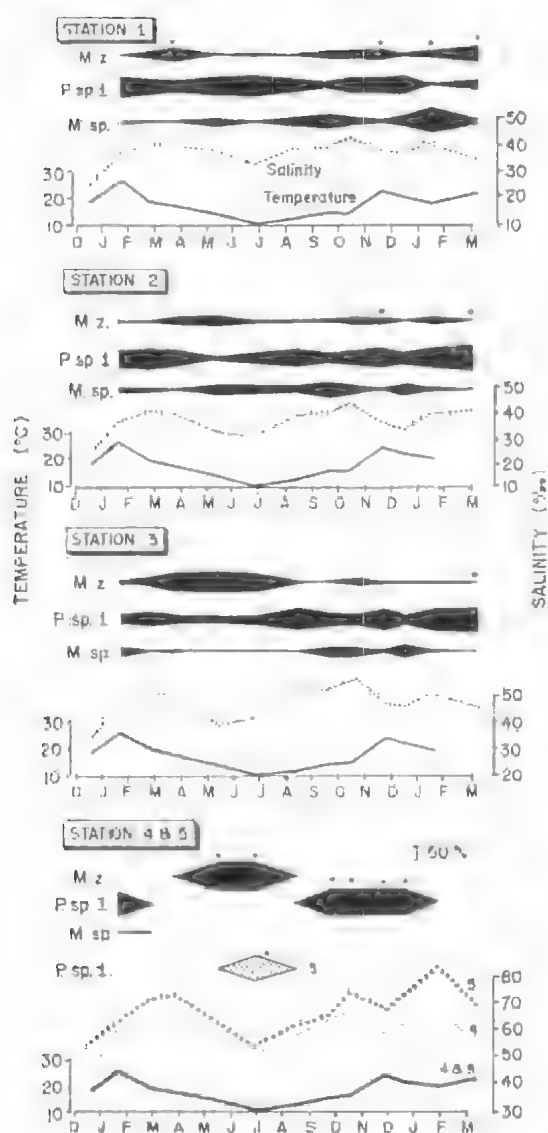


Fig. 3. Seasonal fluctuations in temperature and salinity and the relative abundance (%) of *M. zeylanica* (M.z.) *Paracorophium* sp. (P.sp.) and *Megamphopus* (M.sp.) from Dec. 1981–March 1983. * indicates times when less than 20 individuals were found in samples. P.sp. 1 from station 5 is represented by an open block.

estuaries, they appear to be particularly well adapted to the extreme conditions met in coastal lagoon systems. Some or all of these three amphipods are present in other Australian coastal lagoon systems as previously indicated.

Laboratory studies on *M. zeylanica* and *Paracorophium* sp. show that they are eurythermal and euryhaline with a salinity tolerance range

of 1–62‰ at the optimal temperature of 18°C. Tolerance at temperature extremes (5°C and 32.5°C) was somewhat restricted but salinities of 50‰ could be tolerated at all temperatures investigated. A wide tolerance range is characteristic of estuarine or coastal lagoon species which experience fluctuations in environmental conditions (McLusky 1967, 1968; Jones 1972; Dorgelo 1976), and studies on the tolerance of two estuarine amphipods, *Orchestia chilensis* (Marsden 1980) and *Corophium volutator* (McLusky 1967) showed a tolerance of 3–51‰ and 2–50‰ respectively. The present study, and the field records of amphipods from 50–80‰ from the Laguna Madre in North America (Hedgpeth 1967), suggest that acclimation in hypermarine environments produced higher salinity tolerance than is normal for estuarine species.

Most work using response surface analysis has involved fish and large decapods. None has involved amphipods. In the present study, response contour lines were more closely spaced than in studies on decapods and fish (Costlow *et al.* 1962; Kinne 1971; Alderice 1972) indicating little individual variability in response. This may relate to the osmotic behaviour of the decapods and fish studied which are osmoregulators, while the amphipods in the present study are probably conformers in hypermarine water. There may be more individual variability in the response of regulators to salinity stress than for conformers.

In 1982, amphipod distribution was not limited by low salinity as is the case in most estuarine systems (Meadows 1964; McLusky 1968; Mills & Fish 1980), but the field distribution of all species was limited by high salinities in the stations further from the mouth of the lagoon. Under the rather stable salinity pattern which persisted throughout 1982, no extensive changes in amphipod distribution were seen. Generally amphipods were restricted to salinities less than 53‰ although sporadic records of a few individuals were made to salinities up to 63‰. These values are somewhat lower than found in the laboratory tolerance studies. Field studies in conjunction with laboratory investigations provide information on other factors affecting distribution. One factor which may explain differences between laboratory results and field distributions is the lag time in recruitment of individuals into an area which has only recently become favourable. It is possible that amphipods were absent from southern stations in the winter months when salinities were apparently suitable because previous high summer salinities there had exceeded tolerance limits. The young have direct develop-

TABLE 3. Comparison of percent females ovigerous and mean egg number per ovigerous female between different stations and different "seasons". Figures for percent females ovigerous based on 10-100 females and for egg number on mean of 5-75 brood pouches. The * represents significant differences between mean egg number (Student's *t*-test, $P < 0.05$).

Station	<i>M. zeylanica</i>		Mean # Eggs	
	% Ovigerous "Summer"	% Ovigerous "Winter"	"Summer"	"Winter"
1	—	33.6	—	9.2
2	79.7	53.3	* {14.6	12.3
3	72.3	65.2	{ 7.4	9.8
<i>Paracorophium</i> sp.				
1	24.7	20.0	* { 1.9	2.7
2	50.4	25.8	{ 4.8	5.8
3	32.8	35.9	* { 4.4	4.9
4	6.0	—	{ 2.0	—
<i>Megamphopus</i> sp.				
1	44.5	22.7	* { 4.3	4.3
2	27.5	28.7	{ 7.9	5.5
3	28.0	31.0	* { 4.2	3.9

ment and so there is no planktonic dispersal phase. Thus, in a system with seasonal and long-term fluctuations in salinity and with animals having poor dispersal abilities, it is possible that there is a time lag between the advent of suitable physico-chemical conditions in an area and the establishment of a viable population.

There were no clear effects of salinity on the reproductive condition of populations. The proportion of ovigerous females and the mean egg number per female showed no seasonal change although summer salinities were considerably higher than those in winter. At stations 1 to 3 there was no major difference in percent ovigerous females but *Paracorophium* sp. from station 4 showed a marked reduction in the percent ovigerous females. For all species there were some differences in mean egg number between stations, with stations 3 and 4 having lower egg number than station 2. This may indicate some lowering of reproductive capacity at higher salinities, but the evidence is not conclusive.

The amphipods form a major part of the macrobenthic fauna of the Coorong, and are probably important in food chains leading to fish and birds. High salinities in the Coorong results in narrowing of the range of distribution and lowering of abundance of amphipods and this may have significant effects on animals further up the food chain.

Acknowledgments

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A NEW SPECIES OF CALAMOECIA (COPEPODA: CALANOIDA) FROM SOUTH AUSTRALIA, AND COMMENTS ON THREE CONGENERS

BY I. A. E. BAYLY

Summary

Calamoecia zeidleri sp. nov., a comparatively large species of *Calamoecia*, is described from fresh waters near Lake Eyre and Oodnadatta.

A NEW SPECIES OF *CALAMOECIA* (COPEPODA: CALANOIDA) FROM SOUTH AUSTRALIA, AND COMMENTS ON THREE CONGENERS

by I. A. E. BAYLY*

Summary

BAYLY I. A. E. (1984) A new species of *Calamoecia* (Copepoda: Calanoida) from South Australia, and comments on three congeners. *Trans. R. Soc. S. Aust.* **108**(3), 147-154, 13 December, 1984.

Calamoecia zeidleri sp.nov., a comparatively large species of *Calamoecia*, is described from fresh waters near Lake Eyre and Oodnadatta.

Two Western Australian populations of *C. lucasi*, which have diverged markedly both structurally and ecologically from populations in the eastern half of Australia and in New Zealand, are described in detail. Both populations have an abnormally large body size for this species, and the clutch size of the females of one is unusually high. A palaeoclimatological explanation for the subspecific divergence of Western Australian populations of *C. lucasi* and *C. gibbosa* from those in the east is presented.

New information is presented on the distribution of *C. canberra*.

KEY WORDS: Copepoda, Calanoida, *Calamoecia*, fresh water.

Introduction

The genus *Calamoecia*, which contains small non-marine calanoids, was revised by Bayly (1961, 1962). A further species was added (Bayly 1979) to bring the total number of described species to 13.

During 1981 and 1982 I examined a series of 80 collections of zooplankton made by Mr Wolfgang Zeidler of the South Australian Museum (SAM) from inland waters of South Australia and the Northern Territory. Included amongst this material were five collections from the northern part of S.A. (to the north of Oodnadatta and west of Lake Eyre) which contained a highly distinctive undescribed species of *Calamoecia*. This is described below.

Additionally, two isolated and peculiar populations of *C. lucasi* Brady sampled during the field work associated with the paper of Geddes *et al.* (1981) on saline lakes in Western Australia (but not recorded in that work because of their occurrence in fresh waters) and passed on to me are described.

Possible reasons for the east-west divergence in the morphology of *C. lucasi* and *C. gibbosa* are discussed.

Finally, new information is presented on the distribution of *C. canberra* Bayly hitherto known from few localities but which occurred in 15 of the Zeidler collections.

Although two species of *Calamoecia* occur in saline waters, and saline waters are common in those general regions of Australia referred to in this paper, all *Calamoecia* material discussed below came from fresh waters.

Calamoecia zeidleri sp.nov.

FIGS 1-2

Type Material: Holotype ♂, allotype ♀, paratypes 30♂, 30♀ (from swamp 29°57'S., 136°14'E) nr Billa Kalina Hstd; holotype and allotype stained with Chlorazol Black, dissected and mounted in balsam on microslides; paratypes preserved in formalin, unmounted in vial; SAM C. 3961-7. Paratypes from dam nr William Creek (28°55'S., 136°20'E.) 30♂, 30♀, unmounted in formalin in vial; SAM C. 3969-70.

Description of Male:

Size. (a) Swamp nr Billa Kalina Hstd; mean (n 10) length to end of uropods (formerly furcal rami) 1.10 mm. (b) Dam 16 km N. William Creek; mean length as above 0.99 mm.

Fifth legs (Figs 1A-1B). Right exopod with comparatively short proximal segment, middle segment with tooth on inner edge slightly proximal of mid point and second tooth on outer distal edge near point of insertion of seta on posterior face (Fig. 1A), distal claw strongly bent inwards through approximate right-angle (as in *C. gibbosa*) then curving outwards towards distal extremity, lacking secondary spur (present in seven other species of *Calamoecia*) on inner proximal edge of claw; right endopod 2-segmented, proximal segment only about 1/3 length distal segment, distal segment with highly distinctive thumb-like spur arising at outer distal corner and orientated at right-angles to long axis of segment, with two long spines at distal extremity, that next to "thumb" (= "index finger") strongly curved near base, minute spine occasionally present at inner distal corner near base of inner distal spine (Fig. 1A); left exopod 2-segmented on anterior face (Fig. 1B) but line of segmentation largely obscured on posterior face (Fig. 1A), distal

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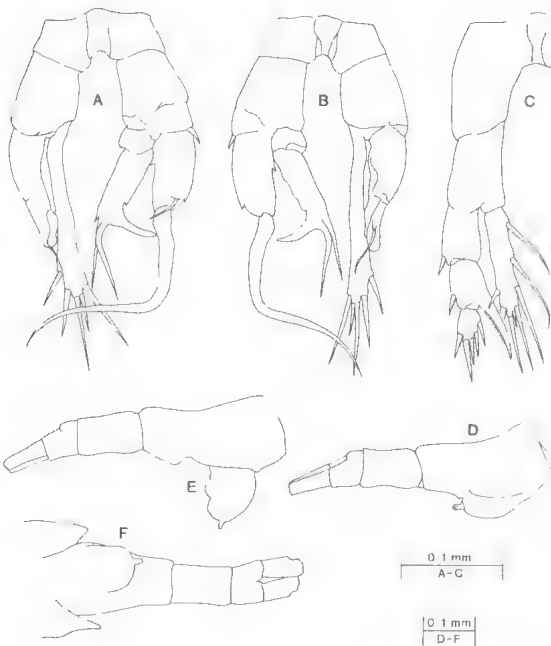


Fig. 1. *Calamoecia zeidleri* sp. nov. A and B, ♂ fifth legs, showing posterior and anterior aspects, respectively; C, ♀ fifth leg; D and E, lateral aspect of ♀ urosome showing, respectively, the ventral bulge, or genital operculum, closed and open; F, ♀ urosome, ventral aspect.

segment with conspicuous seta inserted short of extremity on anterior face and with elongate concavity on posterior face near inner edge; left endopod 1-segmented expanded distally and typically with five spines—two (1 long, 1 short) terminal, two sub-terminal, and one on outer edge ⅓ of total length of segment from distal extremity.

Description of Female:

Size. (a) Swamp nr Billa Kalina Hstd: mean (n = 10) length to end of uropods 1.42 mm. (b) Dam 16

km N. William Creek: mean length as above 1.26 mm.

Fifth legs (Fig. 1C). Terminal exopod segment with five spines, largest or terminal spine only slightly longer (ca 1.3x) than segment itself (compare with most species of *Calamoecia* in which terminal spine > 2 x length segment); endopod 1-segmented bearing eight (or occasionally seven) setae, seta immediately to inside of terminal seta very short and spine-like.

Genital segment (Figs 1D–1F). No lateral outgrowths (Fig. 1F) as in *C. gibbosa*, *C. clitellata* and W.A. forms of *C. lucasi*, genital operculum with distinct posterior “nipple” as in *C. lucasi*, *C. australica* and *C. canberra*.

Remarks: This species is easily recognised by the large outer distal spur on the right endopod of the fifth legs in the male, and by the relatively short terminal spine on the terminal exopod segment of the fifth legs in the female. In the latter feature only *C. salina*, in which the terminal spine is about 1.6x the length of the segment bearing it, approaches *C. zeidleri*. In *C. salina*, however, the terminal exopod segment of the female fifth legs bears only two spines (cf five in *C. zeidleri*).

The body size of the female of this species is relatively large for *Calamoecia* and may be compared with that of the female of *C. attenuata*.

C. zeidleri coexisted with *C. canberra* Bayly at all five localities and also with *Boeckella triarticulata* (Thomson) at three of the five localities. The size relationships existing for one situation in which *C. zeidleri* was one of three coexisting calanoids, and another in which it was one of two, are shown in Table 1. There was no overlap in the mean lengths of the adults of different species.

Congeneric occurrences are not common for *Calamoecia* in Australasia as a whole (cf. Bayly &

TABLE 1. *Size relationships of coexisting calanoids.*

Species and sex	Swamp near Billa Kalina H.S.		Dam 16 km N. William Creek	
	\bar{x} (n=10) length (mm)	\bar{x} ♀ length \bar{x} ♂ length	\bar{x} (n=10) length (mm)	\bar{x} ♀ length \bar{x} ♂ length
<i>Boeckella triarticulata</i> (Thomson)		1.17		
female	1.81			
male	1.55			
<i>Calamoecia zeidleri</i> sp. nov.		1.29		1.27
female	1.42		1.26	
male	1.10		0.99	
<i>C. canberra</i> Bayly		1.16		1.13
female	0.88		0.77	
male	0.76		0.68	

Williams 1973, table 6:3). However, they are not uncommon in the far south-west of W.A. where *C. attenuata* may coexist with a smaller *Calamoecia* such as *C. tasmanica* or *C. elongata*.

Table 1 shows that the ratio (mean female length):(mean male length) for *C. zeidleri* is relatively high (1.27-1.29) for *Calamoecia* (cf. Bayly 1978, table 1, group C).

Material Examined: S.A.: Swamp (Devils Playground) 6 km S.E. of Billa Kalina Hstd (29°55'S., 136°11'E.), 45♂, 40♀, 5.xii.1974; dam 16 km N. of William Creek (28°55'S., 136°20'E.), 45♂, 40♀, May 1976; dam 35 km N. of William Creek, 1♂, May 1976; Alberga Creek road crossing 47 km N.N.W. of Oodnadatta, 1♂, 3.v.1976; waterhole 5 km N. of Mt Sarah (26°55'S., 135°20'E.), 2♂, 4.v.1976; all five coll. W. Zeidler. The distribution is shown in Fig. 2.

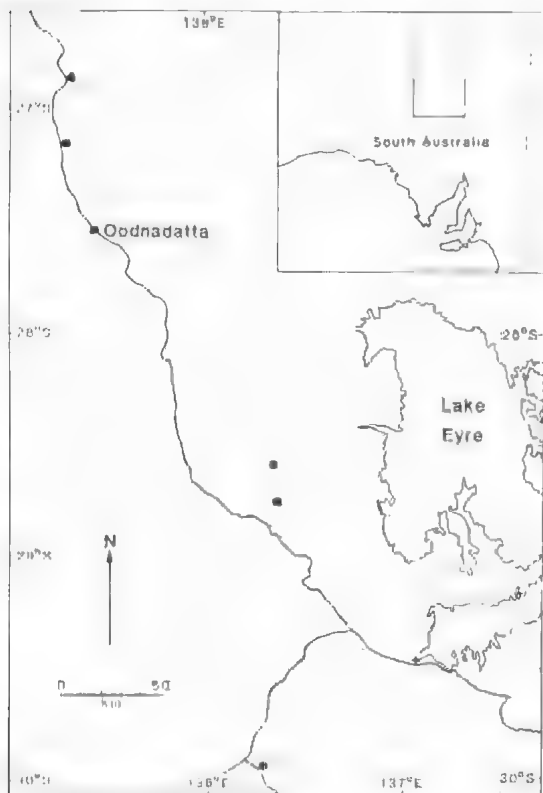


Fig. 2. Distribution of *Calamoecia zeidleri* sp. nov.

Isolated Western Australian populations of *Calamoecia* and their marked morphological divergence

Calamoecia lucasi Brady

As shown by Bayly & Williams (1973, Fig. 6:3), and as indicated in Fig. 3, most Australian popula-

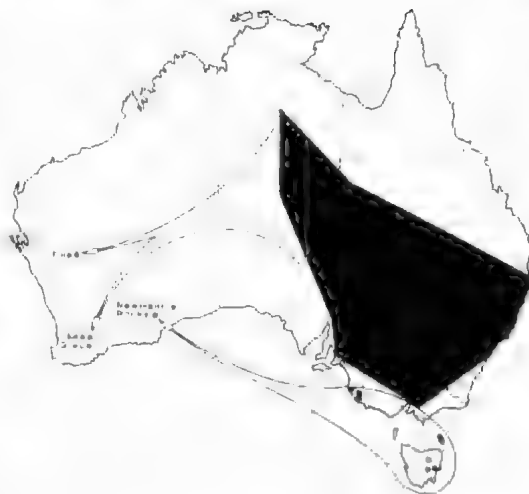


Fig. 3. The main, eastern areas of Australia occupied by *Calamoecia lucasi* and *C. gibbosa* and the isolated W.A. populations of these species. The arrows indicate extensions to previously known distributions—not directions of dispersal.

tions of *C. lucasi* are restricted to the eastern half of the continent (the species also occurs in the North Island of New Zealand). However, the existence of some isolated populations in what are almost certainly temporary waters in arid regions of W.A. is now known. These W.A. populations have diverged remarkably, both morphologically and ecologically, from those in the eastern half of Australia and N.Z. The morphological divergence is evident with respect to both body size, which is much larger, and the details of secondary sexual characteristics. If one of these W.A. populations was transported to N.Z., I doubt if it would be immediately recognised as *C. lucasi* when first encountered there. The possibility exists that breeding experiments would justify the W.A. form being treated as a separate species. However, I consider the aberrant W.A. populations are properly referable to *C. lucasi*.

(a) The Cue Population FIGS 4A-D

Material Examined: W.A.: 20♀, 10♂, pond close to Nallan (27°16'S., 117°59'E.) 21 km N.N.E. of Cue, coll. M. C. Geddes *et al.*, viii.1978.

Body Size (mean prosome length). Female, 0.96 mm ($n = 10$); male 0.86 mm ($n = 10$).

Male Fifth Legs (Figs. 4A and 4B). These differ from those of eastern populations as follows: (1) the proximal segment of the right exopod has no projection at the inner distal corner (compare Figs. 6A and 6B)

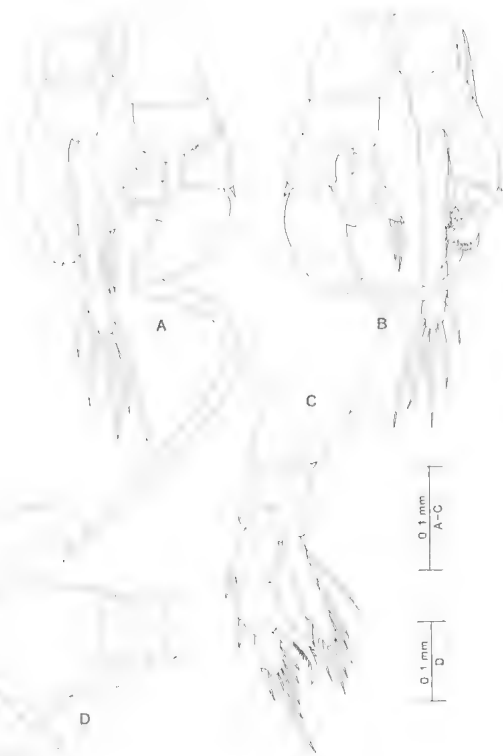


Fig. 4. *Calamoecia lucasi* Brady from population near Cue, W.A. A and B, ♂ fifth legs, showing posterior and anterior aspects, respectively; C, ♀ fifth leg; D, ♀ genital segment (and extensions of last prosomal segment), dorsal aspect.

- (2) there is a strong projection on the inner edge of the middle segment of the right exopod which is not seen in eastern populations
- (3) the distal segment, or terminal hook, of the right exopod is more strongly bent
- (4) the middle segment of the right endopod is enlarged so as to present a semicircular outer edge
- (5) the left endopod invariably has an armature of 5 spines (2 terminal, 3 sub-terminal) instead of the usual four spines; however, variation in spine number from two–five has already been documented (Bayly 1961)
- (6) there are quite strongly developed denticles at or near the distal extremity of the left exopod

Female Fifth Legs (Fig. 4C). The distal exopod segment differs from that of eastern populations in bearing six spines instead of the usual five.

Female Genital Segment (Fig. 4D). This differs from that of eastern populations in having a more pronounced lateral bulge on the left side (compare Figs 6E and 6F).

Clutch Size. The mean number of eggs was an unusually (for this species) high 44 (Table 2).

Remarks: *C. lucasi* was the sole calanoid present in the zooplankton collection from this site which had a maximum depth of about a metre, a very high turbidity, and a T.D.S. value of 41 mg/l. The temporary nature of the pond was emphasised by the presence in the collection of an abundance of conchostracans. Also present were ostracods, cyclopoids, *Chydorus* and *Keratella*.

(b) *The Population Near Lake Grace* FIGS 5A–5F

Material Examined: W.A.: 10♂, 10♀, roadside pool on northern side of road, 3.5 km W. of Lake Grace township, coll. M. C. Geddes *et al.*, viii.1978.

Body Size (mean prosome length). Female, 1.00 mm (n = 10); male, 0.93 mm (n = 10).

Male Fifth Legs (Figs 5A–5C). These differ from those of eastern populations as follows:

- (1) the proximal segment of the right exopod has a more strongly developed projection at the inner distal corner
- (2) the distal segment, or terminal claw, of the right exopod is more strongly bent, as for the Cue population
- (3) the terminal segment of the right endopod typically (Figs 5A and 5B) has one or two greatly reduced, or only vestigial, setae, but occasionally (Fig. 5C) a longer seta is present
- (4) the left leg has the same peculiarities as described above for the Cue population

Female Fifth Legs (Fig. 5D). These have the same peculiarity as detailed above for the Cue population.

Female Genital Segment (Figs 5E and 5F). This is distinctive in being essentially similar to that described above for the Cue population although the left lateral outgrowth is even more pronounced.

Remarks: Two other calanoid species, *Boeckella opaqua* Fairbridge and *B. robusta maxima* Sars, were also present in the collection examined. Both of these species are characteristic of shallow, temporary waters. A T.D.S. value of 980 mg/l was obtained for a water sample taken from the pool.

(c) *C. lucasi* from New Zealand FIGS 6A–6F

Drawings of material collected by the author from Lake Alice (40°08'S, 175°20'E) near Marton,

TABLE 2. Length and clutch size of *Calamoecia lucasi* females.

Nature and location of population	\bar{x} prosome length (mm)	No. females examined	Clutch size \bar{x} no. eggs	Coeff. var. (%)
(A) <i>W.A. seasonal temporary-water populations</i> ¹				
Pool near Lake Grace ^b	1.00	20	44.1	12
Pond near Cue	0.96			
(B) <i>N.Z. perennial lacustrine populations</i>				
Lake Ototoa	0.57 ^c	25	1.8-1.9	
Lake Rotorua	0.65 ^c		3.3 ^c	26 ^c
Lake Rotiti	0.64 ^c		2.0 ^c	27 ^c
Nowell's Lagoon ^d	~		13.8	21

^a Length data from 10 individuals measured along a mid-dorsal line and omitting the well developed, posteriorly projecting "wings" on the last segment of the prosome.

^b No ovigerous females present

^c From Green (1976, table 5). The data represent annual means obtained from the measurement of a large number of individuals from each of a substantial series of samples.

^d From Bayly (1961, table 2)

^e From Chapman (1973, table 3). Mean data from a large number of individuals collected over a two- to three-year period.

N.Z., are included for comparison with the W.A. populations.

Discussion

As shown in Table 2, individuals from these two desert populations of *C. lucasi* are 50% or more (up to 75%) larger than those belonging to N.Z. populations. This probably underestimates the size discrepancy because the prosome measurements of the N.Z. specimens apparently include the postero-lateral "wings" of the last prosomal segment. The type of measurement specified in Table 2 for the W.A. specimens although slower is preferable because of intraspecific variation in the relative degree of development of these wings.

Gigantism in calanoids in Australian desert pools is noted by Mitchell (1984) who referred to *Boeckella triarticulata* reaching a length of up to 3.2 mm in a temporary pool near Lake Eyre. However, Mitchell's explanation, "Organisms in these localities often attain very large sizes due to rapid growth rates [my emphasis]" seems invalid; in planktonic crustaceans large adult body size is associated with long development time (slow growth) and both of these correlate with low temperature alone if food is sufficiently abundant (McLaren 1963).

The large clutch size found for the Cue population (Table 2) is in accordance with the principle (Belk & Cole 1975) that where a calanoid species

occurs in both permanent and temporary waters, populations in temporary waters typically have a larger clutch size than those from permanent waters. A larger clutch size also would be expected in this instance because a positive correlation between clutch size and female body size generally applies within the Copepoda (McLaren 1963). It may be noted, however, that in *Boeckella symmetrica* an increased clutch size in temporary waters (Bayly 1979) does not appear to be accompanied by the striking gigantism reported here for *C. lucasi*.

Typically, freshwater species of *Calamoecia* occur in permanent waters (Bayly 1978). The chief exceptions are the W.A. species, *C. attenuata* and *C. elongata*, W.A. populations of *C. ampulla*, and *C. canberra*, all of which occur not uncommonly in temporary waters even if they also occur in permanent ones. Maly (1984) confirms that, considering the genus *Calamoecia* as a whole, it is much less common than *Boeckella* in temporary pools. Timms (1970, table 12) assessed *C. lucasi* as having poorer powers of dispersal in north-eastern N.S.W. than three species of *Boeckella* that occurred in the same area. Additionally, *C. lucasi* seems not to have been recorded from temporary waters in N.Z. Despite these generalizations concerning the genus *Calamoecia* as a whole, and *C. lucasi* in particular, at least two W.A. populations of this species undoubtedly are adapted for habitat ephemerality.

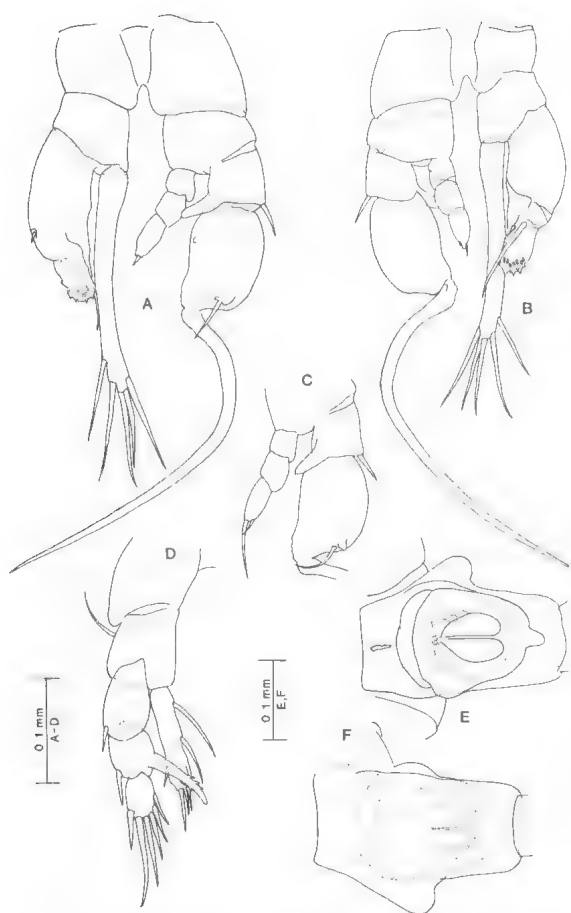


Fig. 5. *Calamoecia lucasi* Brady from population near Lake Grace, W.A. A and B, ♂ fifth legs, showing posterior and anterior aspects, respectively; C, portion of ♂ right fifth leg, showing endopod with (for this population) unusually long terminal seta; D, ♀ fifth leg; E and F, ventral and dorsal aspects, respectively, of ♀ genital segment, showing pronounced outgrowth on left side.

Should the W.A. populations be regarded as relic-tual in character or relatively recent derivatives from the east? Structural evidence favours the former view; the W.A. populations may be regarded as being more primitive in having a less reduced armature on the fifth legs of both sexes (the armature of the male right fifth endopod of the Lake Grace population excepted). The relatively poor dispersal ability of *Calamoecia* (Maly 1984), combined with the fact that westerly or south-westerly winds predominate throughout much of the southern half of Australia, would tend also to favour transport from west to east over the reverse.

Calamoecia gibbosa Brehm

A parallel situation exists for this species as for *C. lucasi* (Fig. 3). For many years *C. gibbosa* was

known only from south-eastern Australia. It was first described in 1950 from Lake Dulverton in Tasmania. Two further Tasmanian records and one from Flinders Island were added by Bayly (1964), and three mainland records (all lakes at or near Mt Gambier) were added by Bayly & Williams (1964). Two further unpublished records (a fourth Tasmanian locality and a second one on Flinders Island), making nine in all, were known at the time of preparation of the map presented by Bayly & Williams (1973) for *C. gibbosa* showing it restricted to south-eastern Australia. However, in 1977 an isolated population was found at Newmann's Rocks in W.A. (Fig. 3) and described by Bayly (1979) as a new subspecies, *C. gibbosa newmannensis*.

A previously unpublished record of *C. gibbosa gibbosa* (incorporated into Fig. 3) is that from Fresh Dip Lake between Beachport and Robe at 37°16'S., 139°49'E. (collection 1.xi.1979).

General Discussion of Western Australian Forms of *C. lucasi* and *C. gibbosa*

The situation described above for *C. lucasi* and *C. gibbosa* is not unlike that recognized by Bayly (1961) for *C. tasmanica* (Smith), with *C. tasmanica tasmanica* in the east, and *C. tasmanica subattenuata* in the west [the position with *C. tasmanica* is,

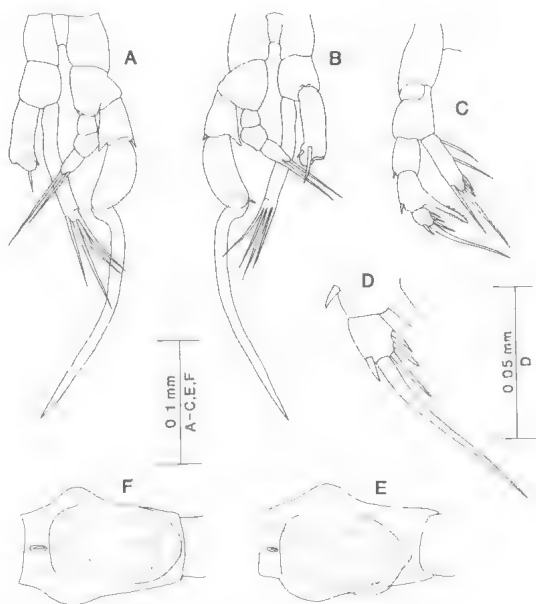


Fig. 6. *C. lucasi* Brady from Lake Alice near Marton, New Zealand. A and B, ♂ fifth legs, showing posterior and anterior aspects, respectively; C, ♀ fifth leg; D, terminal exopod segment of ♀ fifth leg enlarged; E and F, ♀ genital segment, dorsal aspect (different individuals and orientations).

however, more complex than originally supposed (Bayly 1979)). What explanation can be offered for the subspecific divergence of W.A. populations of *C. lucasi* and *C. gibbosa* (and *C. tasmanica*) from those in the eastern half of Australia?

In the early Miocene, 20 million years ago, the environment on the southern coast of Australia was subject to high humidity that penetrated far into the continent (Bowler 1982). There were extensive freshwater lakes in the interior where now salt lakes dominate. Despite a summer maximum in the rain fall, Bowler (1982) considered that even in winter surplus moisture prevailed right across the continent and inland foggy conditions were common. With such a climate it might be supposed that populations of freshwater calanoids such as *C. lucasi* and *C. gibbosa* extended freely across the continent from east to west (except that marine transgressions into the Eucla and Murray basins would have interrupted the continuum along the southern border). Subsequently, however, the development of an intense zone of aridity in the Nullarbor region and its northward extension seems likely to have split the east-west continuum into two segments, the eastern being somewhat larger than the western one. In late Miocene times, six million years ago, there was intense seasonal aridity (winters were now dry) across southern Australia reaching a maximum in the Nullarbor region. In the late Pliocene, 2.5 million years ago, the present climatic zonation of Australia developed for the first time, and by one million years ago central Australia was already dry without necessarily being as arid as subsequently (Bowler 1982). However, there was a major phase during the late Pleistocene from 30-50 000 years B.P., the Mungo lacustrine phase, of lake expansion and (allowing for a reversal of seasonality in precipitation) a return almost to the conditions described for the early Miocene.

The W.A. populations of *C. lucasi* and *C. gibbosa* may be regarded as relictual, and a product of geographical isolation by arid north-south dissection of a previous east-west continuum. But which of the arid dissections was the operative one? In the absence of a fossil record we can presently say little concerning rates of evolution in calanoid copepods. However, the fact that we are dealing with only subspecific levels of differentiation would tend to suggest that an interruption to gene flow occurred in the late Pleistocene rather than at some earlier time. It is reasonable to suggest, therefore, that the relevant dissection post-dated the 30-50 000 years B.P. Mungo lacustrine phase referred to by Bowler (1982), but not the period of maximum aridity 18 000 years B.P.

The question still remains as to why populations of *C. lucasi* and *C. gibbosa* are not now found in the wet far south west corner of W.A. (say to the south-west of a straight line from Busselton to Albany). One can only suppose that, although these species had almost continuous and extensive east-west distributions prior to dissection by an arid corridor through the Nullarbor region, they did not extend to the extreme south-west of W.A., and have been unable to achieve dispersal there since.

It may be noted that the population of *C. lucasi* near Cue inhabited a body of water that was probably at least partially of man-made origin; field notes stated that the depression was "likely to have been artificially deepened". The man-made nature of the pond occupied by *C. gibbosa* at Newmann's Rocks was emphasised by Bayly (1979). Populations of *C. lucasi* and *C. gibbosa* in the desert regions of W.A. must have been very sparse in recent times before the advent of European man, and it is possible that man-made excavations have allowed significant expansion of populations this century.

An alternative interpretation to that presented above is that the W.A. populations of *C. lucasi* and *C. gibbosa* represent recent penetrations from the east, such movement perhaps being favoured by anthropogenic modification of desert habitats. This, however, apparently runs counter to the morphological evidence in the case of *C. lucasi*.

Distribution of C. canberra Bayly

The triangular distribution shown for *C. canberra* by Bayly & Williams (1973, fig. 6c) was based only on five records; the top left apex was for two dams close to Alice Springs, the top right apex was for two lakes (Barcoorah and Dunn) near Aramac, and the bottom apex was for the type locality, Lake George, near Canberra. New records, summarised and combined with the older ones in Fig. 7, are as follows:

S.A.: Kite's dam nr Farina (30°04'S., 138°17'E.), 27.xi.1974; waterhole nr Dulkadirra (29°01'S., 138°28'E.) Birdsville Track, 1.xii.1974; Cooper Creek crossing in Nadadarra H.S. (28°45'S., 138°38'E.) Birdsville Track, 1.xii.1974; dam S. of L. Phibbs (29°32'S., 137°09'E.) on road to Stuart Creek Station, 3.xii.1974; swamp (Deeds Playground) 6 km S.E. of Billa Kalina H.S. (29°55'S., 136°31'E.), 5.xii.1974; Beresford Dam E. of William Creek (28°55'S., 136°20'E.), 6.xii.1974; Paradise Dam 19 km N. of William Creek, 7.xii.1974; dam 16 km N. of William Creek, 8.1976; dam 35 km N. of William Creek, 6.1976; Alberga Creek road crossing 46 km S.W. of Oodnadarra, 3.x.1976; waterhole 5 km N. of Mt Sarah (26°55'S., 135°20'E.), 3.x.1976; all 11 coll. W. Zeidler. Beresford railway dam (29°14'S., 136°39'E.), 1978, coll. B. D. Mitchell. Dam nr Carrington (32°26'S., 138°32'E.), 16.xii.1970, coll. M. C. Geddes, Qld; 1. Koolivoo (21°55'S., 139°35'E.) 65 km S. of Bedourie, 18.x.1977; Longreach waterhole (22°46'S., 138°51'E.) between Glenormiston and Roxborough Downs stations, 20.x.1977,

both coll. W. Zeidler. N.S.W.: Dam 2 km from Wanaaring (29°42'S., 144°09'E.), i.1969, coll. W. D. Williams *et al.* Pond 16 km S.W. of Narrandera (34°45'S., 146°33'E.), 10.v.1982, coll. E. J. Maly. N.T.: Waterhole under McGrath Creek bridge 47 km N. of Alice Springs (23°19'S., 133°47'E.), 20.iv.1979; roadside ditch 7 km N. of Stirling (21°44'S., 133°46'E.), 20.iv.1979; both coll. D. Black.

These records show that *C. canberra* is widely distributed in the central arid portions of Australia to the east of the eastern border of W.A. Most of the water bodies from which it has been recorded are specifically described as being shallow and highly turbid.

Acknowledgments

I wish to thank W. Zeidler and other collectors mentioned above for providing me with the material on which this account is based.



Fig. 7. Distribution of *Calamoecia canberra* Bayly.

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A NEW SPECIES OF THE GENUS RHEOBATRACHUS (ANURA: LEPTODACTYLIDAE) FROM QUEENSLAND

BY MICHAEL MAHONY, MICHAEL J. TYLER & MARGARET DAVIES

Summary

A leptodactylid frog *Rheobatrachus vitellinus* sp. nov. is described from the Clarke Range near Mackay, Queensland. The new species is larger than the gastric brooding frog *R. silus*, and is distinguished from it by a suite of external and internal characters. The two species are separated by a distance of approximately 800 km.

A NEW SPECIES OF THE GENUS *RHEOBATRACHUS* (ANURA: LEPTODACTYLIDAE) FROM QUEENSLAND

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Summary

MAHONY, M., TYLER, M. J. & DAVIES, M. (1984) A new species of the genus *Rheobatrachus* (Anura: Leptodactylidae) from Queensland. *Trans. R. Soc. S. Aust.* **108**(3), 155-162, 13 December, 1984.

A leptodactylid frog *Rheobatrachus vitellinus* sp. nov. is described from the Clarke Range near Mackay, Queensland. The new species is larger than the gastric brooding frog *R. silus*, and is distinguished from it by a suite of external and internal characters. The two species are separated by a distance of approximately 800 km.

KEY WORDS: Anura, Leptodactylidae, chromosomes, *Rheobatrachus vitellinus* sp. nov.

Introduction

The frog *Rheobatrachus silus* Liem (1973) was demonstrated by Corben *et al.* (1974) to be unique in the Animal Kingdom in brooding its young in its stomach, and eventually giving birth through the mouth. The histological and physiological modifications that accompany the conversion of a stomach to a brood sac have been the subject of extensive investigations based in Adelaide, and summarised by contributors to the volume edited by Tyler (1983). More recently other aspects of the cytology, pharmacology and physiology of gastric brooding have been documented by Gibbins & Tyler (1983), Tyler *et al.* (1983), Laidler *et al.* (1984), de la Lanza *et al.* (1984) and Shearman *et al.* (1984).

In the light of the considerable interest in *R. silus*, the sudden demise of the population in 1979 assumed special significance. Despite extensive searches, particularly in 1982-83, not a single representative of *R. silus* has been found, but it is not possible to make a definite statement that the species is extinct.

In January 1984 a new species of *Rheobatrachus* was discovered in the Clarke Range in the vicinity of Eungella National Park, west of Mackay, Queensland, approximately 800 km north of the known geographic range of *R. silus*. Here we describe the new species.

Materials and Methods

The specimens reported here are deposited in museum collections abbreviated as follows: AM Australian Museum, Sydney; QM Queensland Museum, Brisbane; SAM South Australian Museum, Adelaide.

Methods of measurement and abbreviations employed in the text follow Tyler (1968). Clearing and staining techniques for bone and cartilage are those of Dingerkus & Uhler (1977).

Mitotic chromosomes from one individual (sub-adult female QM J42145) were obtained from short term lymphocyte cultures using standard techniques applied to mammalian cultures (see Sharman *et al.* 1970), the only modification being incubation at 25°C. Whole blood (0.2-0.5 ml) was obtained by heart puncture using a sterile heparinized syringe.

Rheobatrachus vitellinus sp. nov.

FIGS 1-11

Holotype: QM J42529, an adult female collected at Eungella National Park, 148°38'00"E.; 21°01'30"S., Queensland on 27.1.84 by K. R. McDonald and V. R. J. Hansen.

Description of holotype: Head flattened, approximately as long as broad. Snout not prominent, evenly rounded when viewed from above, rounded and projecting slightly in profile. Nares dorsal and inclined superiorly; surrounded by loose, fleshy margin and with small papilla at posterior border. Distance between naris and tip of snout approximately equal to eye to naris distance. Internarial span greater than distance separating eye from naris (E-N/IN 0.80). Canthus rostralis not defined. Eye prominent (Fig. 1).

Tympanum not visible externally. No vomerine teeth. Choanae large, widely separated and surrounded by rim of soft tissue. Tongue large and adherent to floor of mouth. Lower jaw with superior symphyseal prominence inserting into deep diastema between premaxillae. Upper jaw with medial innervation.

Fingers cylindrical with lateral fringe on medial surface of digit II. In order of length 3>4>2>1. Subarticular tubercles very poorly defined, no palmar tubercles. Slightly developed terminal discs

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Fig. 1. Upper: Female *Rheobatrachus vitellinus* in life. Lower left: Ventral aspect of *R. silus*. Lower right: Ventral aspect of *R. vitellinus*.



Fig. 2. *Rheobatrachus vitellinus*. A. Palmar surface of hand. B. Plantar surface of foot.

lacking circummarginal grooves. No interdigital webbing (Fig. 2A).

Hindlegs short (TL/S-V 0.47). Toes long, sub-articular tubercles moderately developed but lacking on metatarso-phalangeal joint of toe IV (Fig. 2B).

Expanded discs on tips of toes larger than those on fingers. Webbing reaching discs of all toes; broad medial flange on toe I. In order of length $4 > 3 - 5 > 2 > 1$. Large flattened inner but no outer metatarsal tubercle. No supernumerary tubercles on foot.

Dorsal skin irregular and foveolate. Large, irregular, bullate projections on upper eyelid. Distinct fold in customary supratympanic position extending from posterior corner of eye to insertion of forearm. Narrow, dermal fold superior to anterior $\frac{1}{3}$ of supratympanic fold. No tarsal fold; few small, prominent tubercles on posterior surface of tarsus. No tubercles on flanks. Anus with fimbriated border. Ventral surface of body and limbs smooth.

After three months in preservative, dorsum mottled irregularly with dark brown and with small patches of cream upon a light brown background. Ventral surface cream with dense stippling of dark brown upon the throat and chest, but becoming more sparse posteriorly. Back of thighs heavily pigmented with dark brown. Palmar and plantar surfaces dark brown. Remainder of ventral surface pale cream.

Osteology:

Cranial Features

Skull poorly ossified; sphenethmoid poorly ossified, modified anterolaterally to form articulating surfaces, normally overlain by cartilaginous



Fig. 3. Dorsal view of sphenethmoid of *Rheobatrachus vitellinus*.

cap (Fig. 3); not in bony contact with nasals, extending $\frac{1}{4}$ length of orbit in ventral view. Elongate small bone located medially above sphenethmoid (Fig. 3). Prootic and exoccipital completely fused dorsally, slight reduction of ossification in pleural region. Crista parotica short and stocky, not articulating laterally with otic plate. Dorsally prootic extended posteromedially to form two flanges dorsolaterally to exoccipital. Frontoparietal fontanelle ovoid except for indented anterior extremity. Frontoparietals well ossified, anterior extremities slender, asymmetrical, not reaching anterior extremities of sphenethmoid. Orbital edges of frontoparietals straight, angled slightly posterolaterally. Anterior margins of frontoparietal fontanelle formed by sphenethmoid at level about $\frac{1}{4}$ anteriorly along length of orbit. Posterior margin about $\frac{3}{4}$ posteriorly along length of orbit (Fig. 4A).

Nasals small, slender, widely separated, expanded anteromedially, horizontal. Nasals not in bony contact with any roofing bones. Palatines broad, curved, unridged, overlying sphenethmoid ventrally to level of anterior extremities of frontoparietals (Fig. 4B). Parasphenoid moderately robust. Cultriform process short, tapering anteriorly, not reaching articulation of anterior ramus of pterygoid. Alary processes arising from ventral flanges in posteromedial region of cultriform process, short, moderately slender and crenate laterally.

Pterygoid extremely robust. Anterior rami in long contact with palatal shelf of maxillary. Medial rami extremely broad, blunt. Posteromedial flange at junction of three rami and ventromedial flange at posterior extremity of anterior ramus. Posterior rami moderately broad, long, acuminate. Quadratojugal robust and entire; squamosals robust with long acuminate zygomatic ramus and shorter expanded otic ramus.

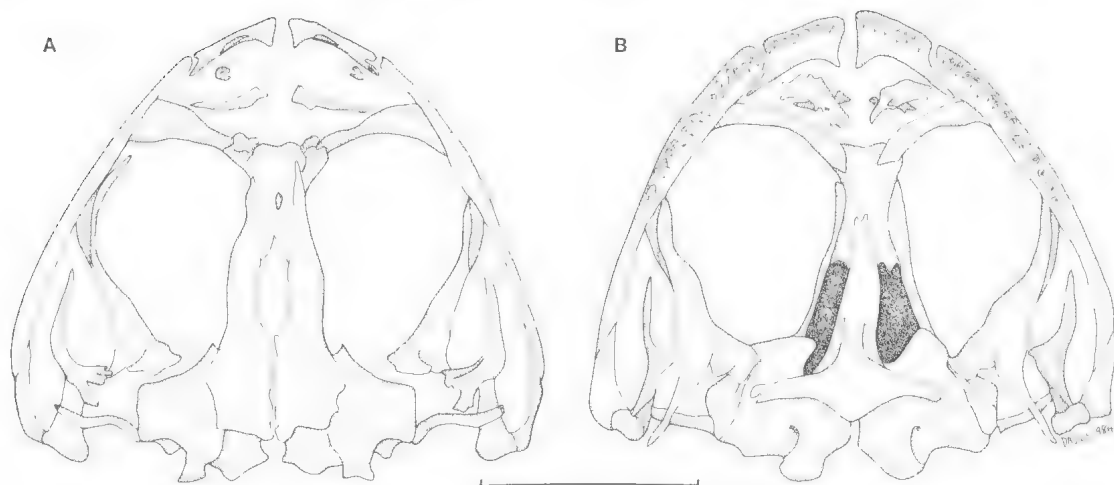


Fig. 4. Cranium of *Rheobatrachus vitellinus*. A. Dorsal aspect. B. Ventral aspect. Scale bar = 10 mm.

Maxillary and premaxillary dentate. Teeth fang-like. Pars facialis of maxillary shallow with well-developed preorbital process, not in bony contact with nasals. Alary processes of premaxillaries short, broad, perpendicular to pars dentalis of premaxillaries, but inclined medially. Palatal shelf well developed with poorly developed palatine processes of premaxillaries. Lateral extremities of palatal shelf of premaxillaries elongated to lie medially to anterior portion of palatal shelf of maxillaries (Fig. 4B). Pterygoid process not developed.

Vomers considerably reduced. Remnant denticulous processes present, but edentate. Alae poorly developed. Bony columella extremely long.

Ligaments joining mentomeckelian bones on lower jaw directed dorsally to form cartilaginous protuberance fitting into notch between palatine processes of premaxillaries. Meckel's cartilages poorly differentiated (Fig. 5C).

Hyoid plate broader than long. Alary processes with broad base, variable shape (Fig. 6). No aperture present on alary process for passage of hypoglossal nerve. Cricoid ring complete. Branchial processes simple, moderately long; oesophageal processes short. Posteromedial processes ossified; cartilaginous tips confined to lateral and medial extremities (Fig. 6).

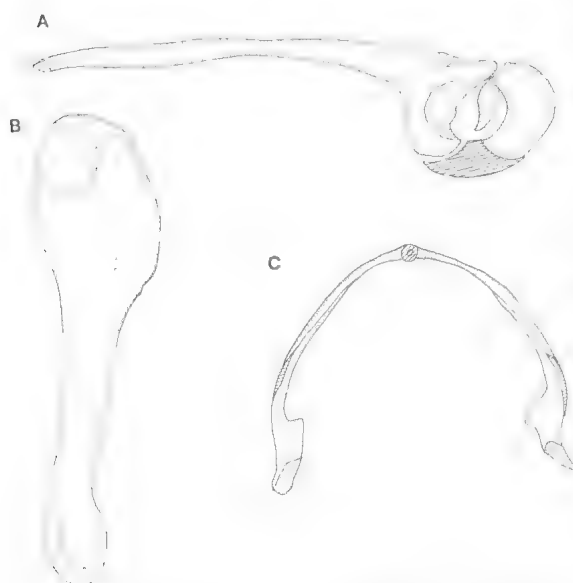


Fig. 5. *Rheobatrachus vitellinus*. A. Left ventral aspect of pelvic girdle. B. Humerus. C. Dorsal view of mandible.

Post Cranial Features

Pectoral girdle arciferal and robust (Fig. 7). Omosternum and ziphisternum present; xiphisternum $\frac{1}{4}$ calcified. Clavicles robust, moderately separated medially. Coracoids robust, widely separated medially. Scapula bicapitate, very broad and stocky. Suprascapula about $\frac{1}{4}$ ossified, proximal and posterolateral edges crenate (Fig. 7).

Well developed anteroproximal crest on humerus (Fig. 5B). Phalangeal formula of hand 2,2,3,3. Distal tips of phalanges knobbed. Six carpal elements present; radiale, ulnare, preaxiale centrale, postaxiale centrale, carpales 2 and 3. Bony prepollex (Fig. 8A).

Eight procoelous presacral vertebrae. Vertebra II imbricate, others non-imbricate (Fig. 9). Relative width of transverse processes $\text{III} > \text{IV} > \text{SD} > \text{II} > \text{V} > \text{VI} > \text{VII} > \text{VIII}$. Sacral diapophyses widely



Fig. 6. Ventral view of hyoid plate and larynx of *Rheobatrachus vitellinus*.

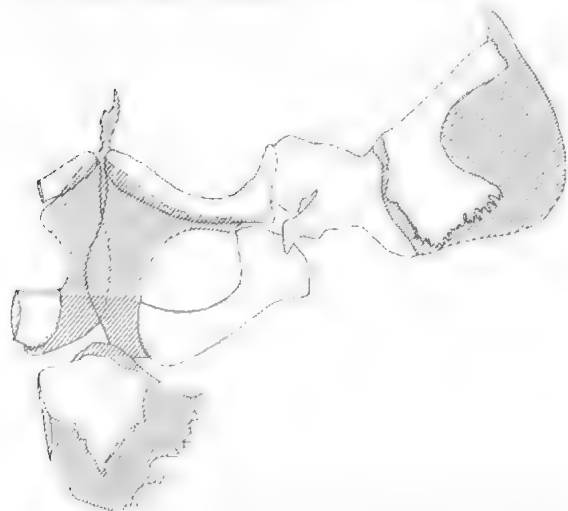


Fig. 7. Dorsal view of pectoral girdle of *Rheobatrachus vitellinus*.

expanded. Bicondylar sacrococcygeal articulation. (Fig. 9). Transverse processes present on urostyle. Urostyle long with poorly developed crest extending about $\frac{1}{4}$ its length. Moderately developed dorsal prominence on ilium; tiny dorsal protuberance (Fig. 5A). Pubis cartilaginous.

Phalangeal formula of foot 2,2,3,4,3. Three distal tarsal elements present; O. fibulare and O. tibiare fused. Small bony prehallux (Fig. 8B).

No sesamoids present on appendages; free epiphysal joints not apparent.

Variation: There are four paratypes: AM R111733 an eviscerated adult male collected at Eungella National Park by K. R. McDonald and V. R. J.

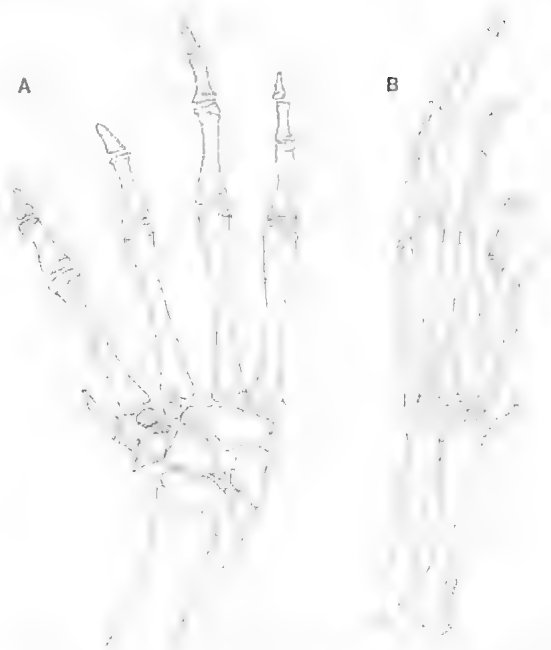


Fig. 8. *Rheobatrachus vitellinus*, bones of A. Hand B. Foot.

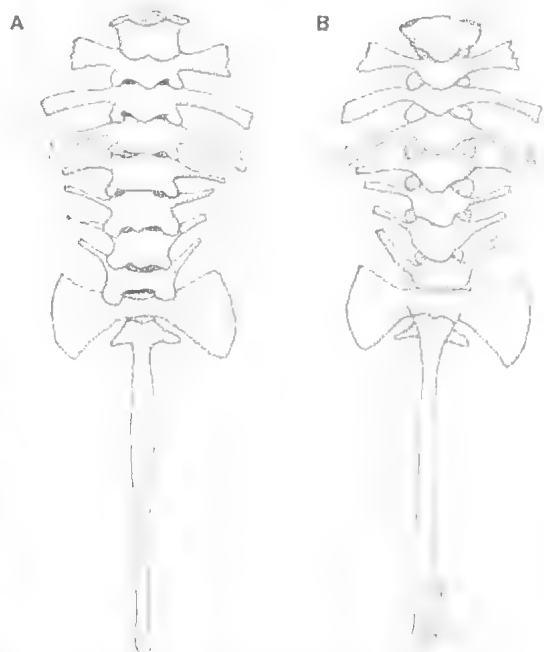


Fig. 9. *Rheobatrachus vitellinus*. Vertebral column. A. Dorsal aspect. B. Ventral aspect.

Hansen on 28.i.84; QM J42145 a sub-adult female collected at Tree Fern Creek, Clarke Range by M. Mahony on 2.i.84; SAM R25447 a cleared and stained adult female collected at Eungella National Park

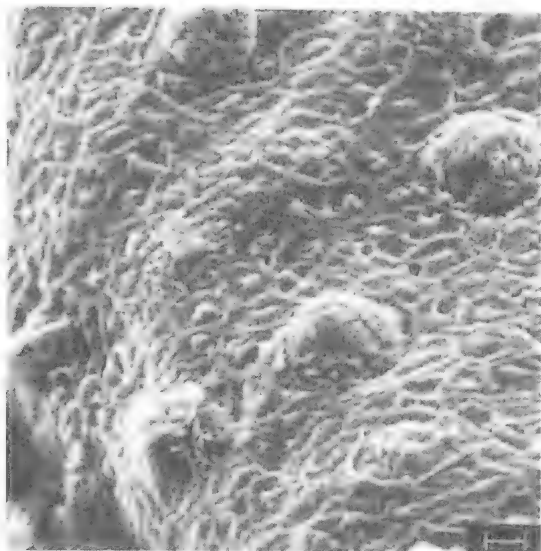


Fig. 10. *Rheobatrachus vitellinus*. Scanning electron micrograph of nuptial pad. Bar = 10 μ m.

by K. R. McDonald and G. Chester on 12.i.84; SAM R25446 an eviscerated adult female collected at Eungella National Park by K. R. McDonald and G. Chester on 10.i.84.

The adult females have S-V lengths of 68.9 mm and 62.2 mm respectively, the sub-adult female measures 41.5 mm and the adult male 55.7 mm.

In their habitus the paratypes do not differ significantly from the holotype. The head proportions are uniform; the eye is protuberant but the E-N/IN ratio is slightly higher (0.86–0.98) compared with 0.80 in the holotype.

The adult male has an unpigmented nuptial pad on the medial and dorsal surfaces of the first digit. With a magnification of 50x it is possible to see that

it is covered with numerous small spines (an SEM illustration is shown in Fig. 10). The male has a vocal sac with paired apertures on the floor of the mouth that are surrounded by fleshy margins.

Colour in life: All specimens examined by us have a pale brown dorsum with obscure darker patches on both the body and limbs (Fig. 1). The ventral surface of adults bears an extensive area of vivid yellowish-orange (Spectrum Orange of Smithe, 1975) covering the limbs and extending for varying distances up the abdomen. There also are patches of similar colour on the undersurface of the arms. The specimen illustrated (Fig. 1) has the remainder of the ventral surface unpigmented but in some individuals it is dark brown.

Karyotype: The karyotype of *R. vitellinus* is shown in Fig. 11; the diploid number is $2n=24$. The chromosomes are arranged in two groups on the basis of size. Pairs 1–6 are large with relative lengths (R.L.) ranging 15%–10%; pairs 7–12 are small with R.L. ranging 6%–3%. Chromosome pairs 1, 5, 7 and 8 are metacentric; pairs 3, 4 and 6 are submetacentric; pair 2 is subacrocentric; pairs 9–12 are acrocentric. A prominent secondary constriction occurs procentrically on the short arm of pair 6.

Comparison with other species: In appearance *R. vitellinus* differs from *R. silus* principally in its larger size and more spectacular ventral colouration. The three adult female paratypes of the new species have an S-V range of 62.2–68.9 mm (and the largest live specimen now in captivity is approximately 83 mm long). This size range compares with 44.5–53.9 mm S-V for 19 female *R. silus* examined by Tyler & Davies (1983). Similarly the sole adult male S-V of 55.7 mm compares with the cited range of 32.9–40.6 mm S-V for *R. silus*.

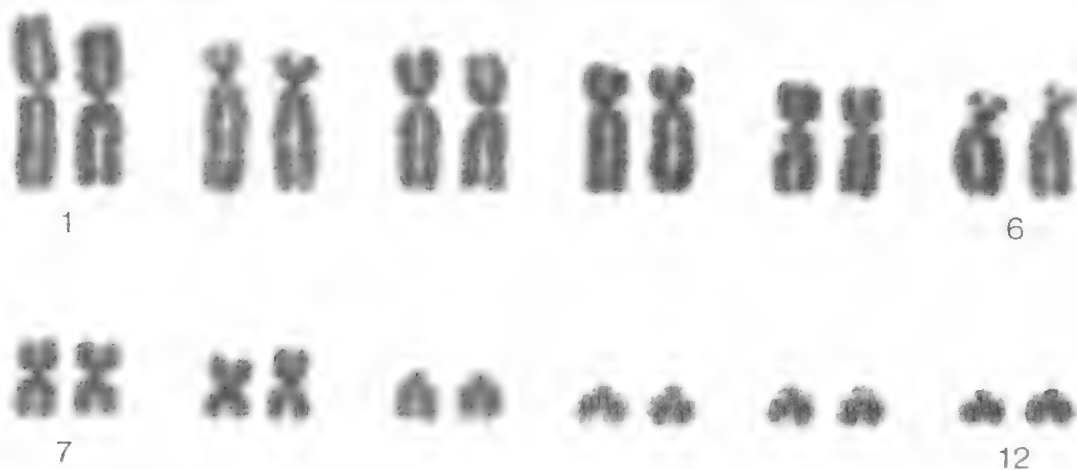


Fig. 11. Karyotype of *Rheobatrachus vitellinus*.

The striking difference in ventral colouration is shown in Fig. 1. *Rheobatrachus silus* has the ventral surface of the hindlimbs very pale yellow compared with the bright and more extensive yellow markings of *R. vitellinus*. No individual of *R. silus* exhibit the brown colouration seen in some, but not all, *R. vitellinus*.

Osteologically *R. vitellinus* differs from *R. silus* in a number of features. Cranially the presence of articulating facets anterolaterally on the sphenethmoid and of posteromedial flanges on the dorsal surface of the prootic, and the small supernumerary bone dorsal to the sphenethmoid are unique to *R. vitellinus* and in fact are not shared by any other Australian leptodactylid. The position of the anterior extremities of the frontoparietals and posterolateral angle of the orbital edges of the frontoparietals differ between the two species. The skull of *R. vitellinus* is more extensively ossified in the crista parietalis region and the frontoparietal fontanelle is less extensively exposed than in *R. silus* (Davies 1983).

Absence of the apertures for the hypoglossal nerve on the alary processes of the hyoid and minimal development of the mentomeckelian cartilages of the lower jaw are features unique to *R. vitellinus* in the genus.

Posteriorly, the arciferal pectoral girdle of *R. vitellinus* (modified arciferal in *R. silus*) separates the two species, as does the crenate edges on the suprascapula and the relative widths of the transverse processes of the presacral vertebrae.

The karyotype of *R. vitellinus* is similar to those of the majority of Australian leptodactylid frogs, including *R. silus*, in diploid number and relative chromosome lengths. When compared with the karyotype of *R. silus* (Morescalchi & Ingram, 1974) differences are apparent in the centromere positions of several corresponding chromosome pairs and in the location of the secondary constriction. The most obvious differences in centromere position occur in pair 6 which is submetacentric in *R. vitellinus* and acrocentric in *R. silus*; pairs 9 and 10 are acrocentric in *R. vitellinus* and metacentric in *R. silus*. A prominent secondary constriction occurs procentrically on the short arm of pair 6 in

R. vitellinus. Morescalchi and Ingram (1974) did not identify any secondary constrictions in the karyotype of *R. silus*, however the acrocentric morphology of pair 6 means that a secondary constriction cannot possibly be in the same position as in *R. vitellinus*. These differences in chromosome morphology indicate that structural chromosomal rearrangements have occurred since the two species had a common ancestor and verify the specific identity of *R. vitellinus*.

Habitat: *Rheobatrachus vitellinus* is an aquatic species inhabiting shallow sections of fast flowing creeks in rain forest. Preliminary observations suggest that the species is confined to areas above approximately 300 m a.s.l. where the creeks flow across granitic rocks. K. R. McDonald currently is examining habitat preferences and distribution of the species.

In January 1984 the only other species of frogs observed at the creeks with *R. vitellinus* were *Todactylus eungellensis* which was active on emergent rocks in the creek beds, and *T. liemi* which was calling from crevices in the creek bank.

Etymology: The specific name is derived from the Latin *vitellinus* 'of the yolk of an egg' and refers to the ventral colouration.

Acknowledgments

We record our gratitude to the Peter Rankin Trust Fund and the Australian Biological Resources Study for funding the visit by one of us (M.M.) which resulted in the discovery of this species. We are also deeply grateful to the Queensland National Parks and Wildlife Service for granting collecting permits, and particularly to Mr Keith McDonald for his enthusiastic cooperation, advice, and the provision of specimens. M.M. thanks S. Bergin, G. Johnston and P. Maidens for field assistance. A visit to the type locality by M.J.T. was made possible by the Australian Broadcasting Corporation. Laboratory studies were funded by a grant to M.J.T. and M.D. by the Australian Research Grants Scheme. The inclusion of colour plates was made possible by a grant from the Mark Mitchell Foundation.

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QUATERNARY CLIMATIC CYCLES, LAKE MILLYERA REGION, SOUTHERN STRZELECKI DESERT

BY R. A. CULLEN

Summary

Following the drying of the very extensive lakes which existed during the Tertiary, there were three complex Pleistocene climatic cycles, or portions thereof, recorded in sedimentary sequences at Lake Millyera near the southeastern margin of Lake Frome. It is suggested these reflect changes in world climate related to glacial/interglacial episodes, though at present dating is only sufficient to identify the younger phase with certainty (16-21 000 years B.P.). The earliest phase records mainly high lake levels, culminating in complete drying of the lake bed (the top of the beach deposits was $+16 \pm 1.5$ m a.h.d., the bed of Lake Millyera is + 4 m, and that of Lake Frome is close to sea level). This was followed by semi-arid fluvial activity and aeolian deposition, during which time Lake Frome regressed to its present shoreline. Watertables were lower than before, but higher than at present. The uppermost sequence represents part of the longitudinal dunes which built the Strzelecki Dunefield, again indicating a drop in watertable, but still periodically higher than present. A new rock unit, the Coombe Springs Formation is defined, and the Millyera Formation redefined.

QUATERNARY CLIMATIC CYCLES, LAKE MILLYERA REGION, SOUTHERN STRZELECKI DESERT

by R. A. CALLEN*

Summary

CALLEN, R. A. (1984) Quaternary climatic cycles, Lake Millyera region, southern Strzelecki Desert. *Trans. R. Soc. S. Aust.* **108**(3), 163-173, 13 December, 1984.

Following the drying of the very extensive lakes which existed during the Tertiary, there were three complex Pleistocene climatic cycles, or portions thereof, recorded in sedimentary sequences at Lake Millyera near the southeastern margin of Lake Frome. It is suggested these reflect changes in world climate related to glacial interglacial episodes, though at present dating is only sufficient to identify the younger phase with certainty (16-21 000 yrs B.P.). The earliest phase records mainly high lake levels, culminating in complete drying of the lake bed (the top of the beach deposits was $+16 \pm 1.5$ m a.h.d., the bed of Lake Millyera is $+4$ m, and that of Lake Frome is close to sea level). This was followed by semi-arid fluvial activity and aeolian deposition, during which time Lake Frome regressed to its present shoreline. Waterables were lower than before, but higher than at present. The uppermost sequence represents part of the longitudinal dunes which built the Strzelecki Dune-field, again indicating a drop in watertable, but soil periodically higher than present. A new rock unit, the Coombe Springs Formation is defined, and the Millyera Formation redefined.

KEY WORDS Quaternary climate, Strzelecki Desert, Lake Frome, Lake Millyera, Coombe Springs Formation, Millyera Formation.

Introduction

Around Lake Millyera in the Strzelecki Desert (Fig. 1) are a number of well-exposed Quaternary sections, two of which have been used to define rock stratigraphic units in the region (Callen & Tedford 1976). These sections contain an excellent record of former climatic fluctuations, relating to the prior expansion and contraction of Lake Frome during the Quaternary. Both these lakes are now playas, which fill occasionally under conditions of exceptional local rains (Callen 1983).

Lake Frome has a critical size in relation to its catchment, such that it should respond to major changes in runoff but not local fluctuations (Bowler 1981). Thus variations in shoreline should reflect significant climatic events. Possibly superimposed on this is the effect of Quaternary uplift of the Flinders Ranges (Callen & Tedford 1976) which might have decreased runoff in the western catchment of Lake Frome by the rainshadow effect.

Past shoreline positions can be identified by appropriate facies changes in the sediments. Degree of aridity can be measured by identifying aeolian sequences, evaporites, and palaeosol horizons, supplemented by fossil evidence. Some limitations are imposed by the lack of accurate height data, lack of knowledge about movements on faults in the vicinity, and problems with radiocarbon dating of calcareous palaeosols (Callen *et al.* 1983).

This short paper describes four sections in detail and their interpretation, and redefines the Millyera

Formation, introducing a new unit, the Coombes Springs Formation (Callen *et al.* 1983). Their significance in relation to world climatic change is assessed.

Results of the Investigation

Lake Millyera is located adjacent to the southeast of Lake Frome, cutting across a series of palaeo-shoreline features. Good exposures of Late Cainozoic sediments are to be found along the northern shore, and in gullies to the southeast (Fig. 1). The northern shore is dominated by low cliffs of the Tertiary Namba Formation dolomite and clay (Callen & Tedford 1976), blanketed by red aeolian and fluvial sands of the Quaternary Period. The best Quaternary sequences are found along the southeastern shore (Fig. 2), where the Namba Formation is not exposed, and in a depression cut into the Namba Formation in the northeastern part of the lake adjacent to the old track crossing (Fig. 1). These Quaternary sequences range from 3 m to 25 m thick, and reveal green lacustrine clays and fine sand, red fluvial sands, and an overlay of two ancient aeolian sequences. Shelly beach deposits form prominent white benches. Calcareous palaeosols and algal limestones are useful markers. The Namba Formation forms a base to the entire sequence, and can be found just beneath the lake floor.

Descriptions of the sections, with interpretations, are presented in Figs 3-6. A summary of correlation and environments appears in Fig. 7.

Thin sections, X-ray diffraction and radiocarbon dating were used to study the sequence.

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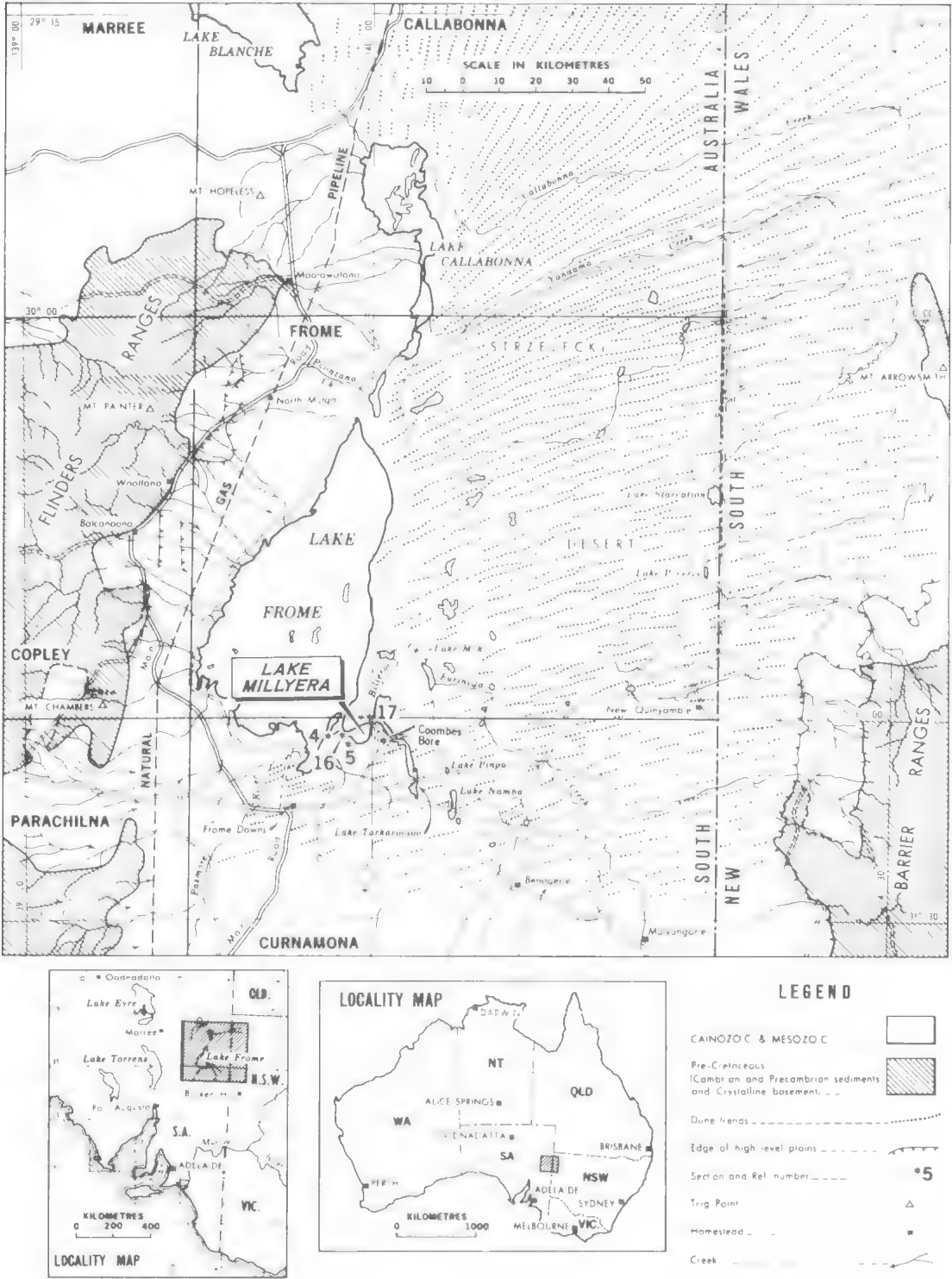


Fig. 1. Location of Lake Milliyera.

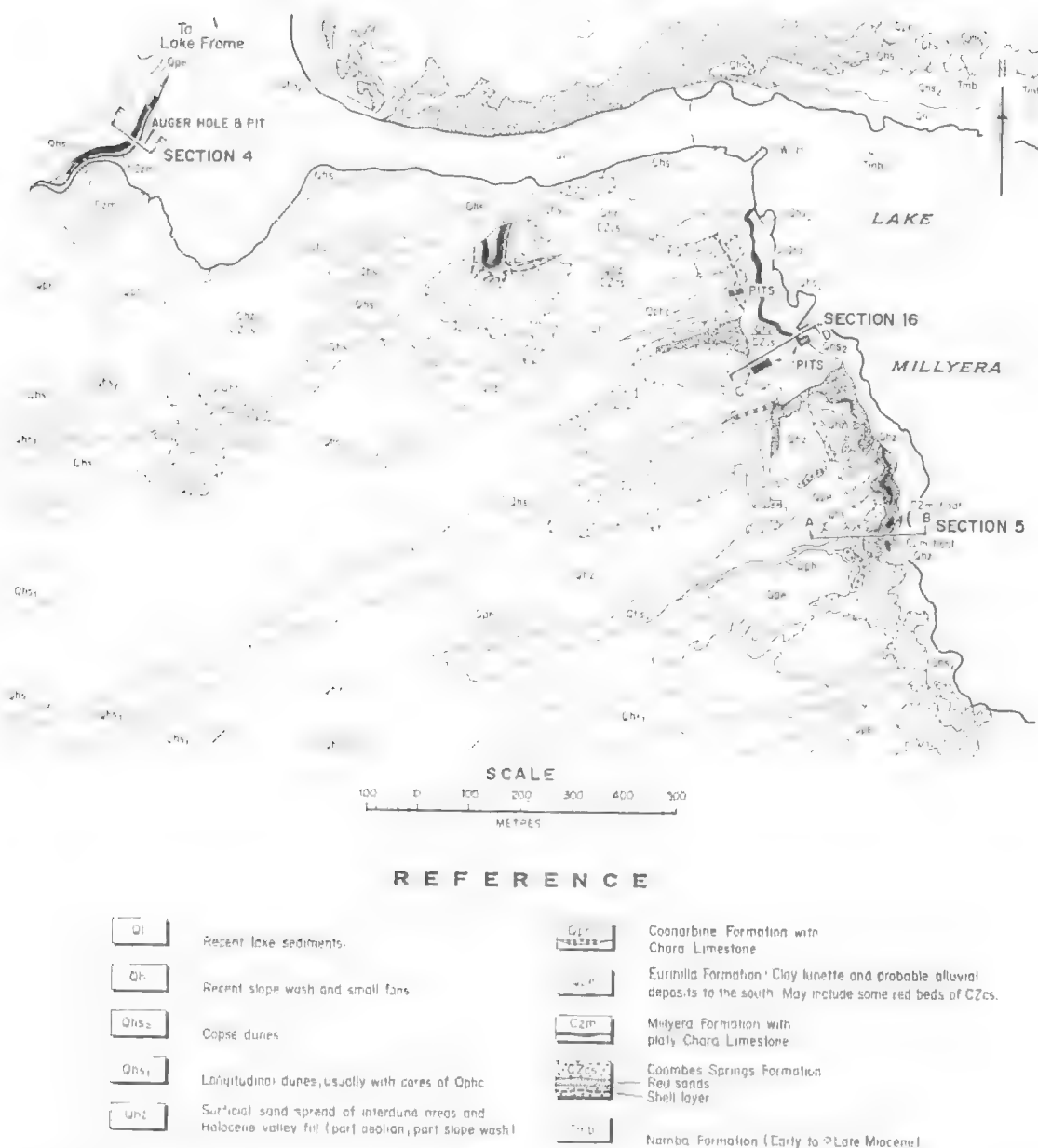


Fig. 2. Western Lake Millyera—geological map and location of sections.

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The sections around Lake Millyera have useful height data and do not have their relationships complicated by faulting. However, similar units to the east may possibly have been affected by northerly-trending structures. Nevertheless, the eastern lakes region offers the potential of resolving older shorelines through detailed drill traverses coupled with accurate height data.

Correlation and Nomenclature

Detailed mapping, and practical aspects of depicting shoreline deposits of different ages on 1:250 000 scale geological maps of the South Australian Department of Mines and Energy (consider the implications of the section, Fig. 8), have lead to redefinition of the Millyera Formation and introduction of a new unit, the Coombes Springs

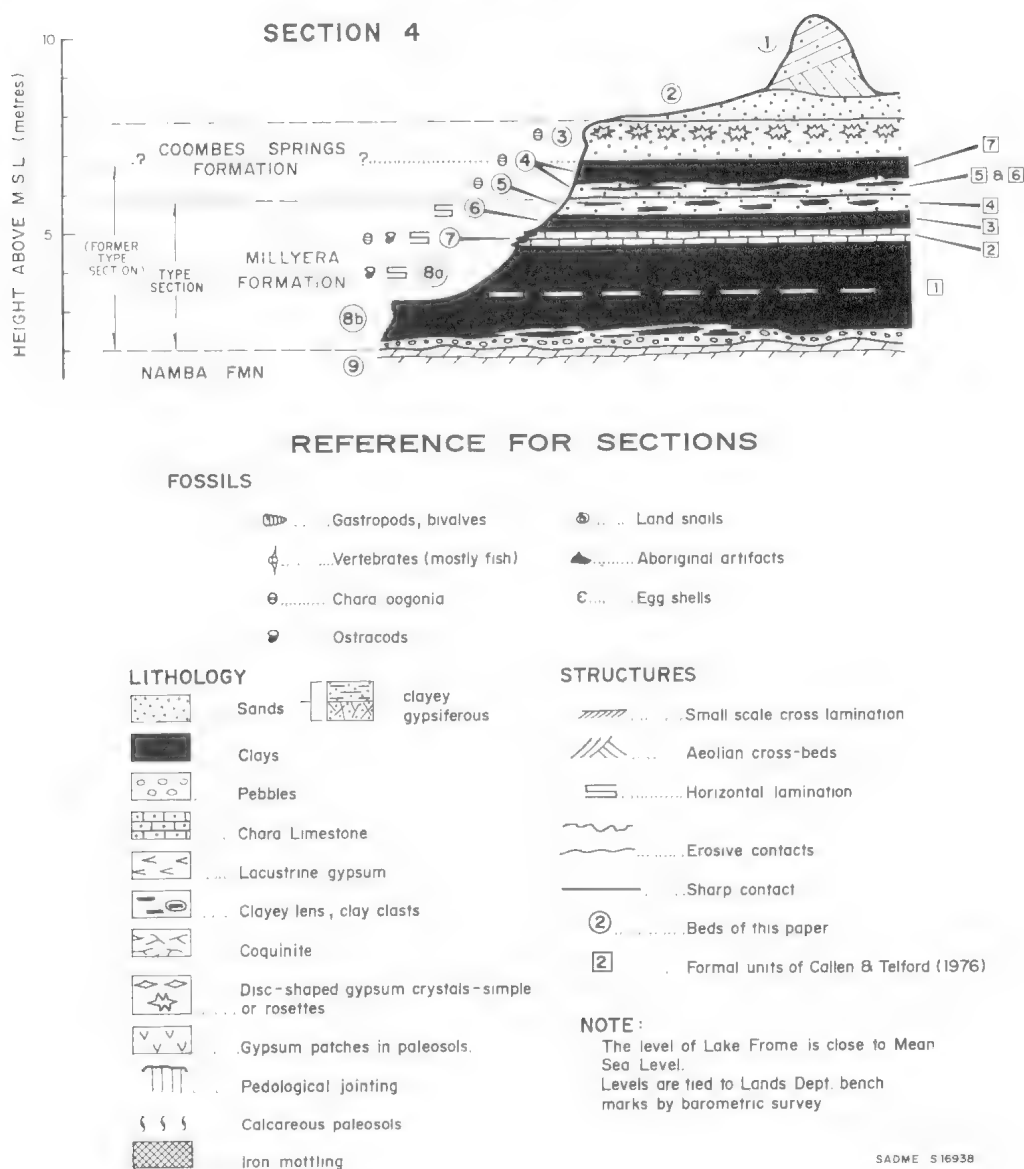


Fig. 3. Lake Millyera section 4, includes Millyera Formation type section.

1. Orange brown loose sand, fine grained, 0.3 m. **Modern longitudinal dune sand.** 2. Coarse sand with gypsum grains and angular milky quartz pebbles, hummocky "cow pat" gypsum crust. 0.7 m. **Interdune deposits of gypsum dunes, gypsum tepees. EURINILLA FORMATION:** 3. Clayey very fine greyish-orange sand with numerous *Chara* oogonia. Multi-coloured grains. Capped by gypsum crust 1.10 m. **Overbank deposits with old saline groundwater horizon (represented by gypsum).** **COOMBES SPRINGS FORMATION:** 4. Soft clay with sharp upper contact, dark yellowish brown. Oxidised and crumbly, grades down by alternation to fine medium sand with *Chara* oogonia. This sediment overlies, with sharp contact, well sorted clayey sand of greenish yellow colour. 1.40 m. **?Lacustrine deposits and ?beach sands, soil profile at top. MILLYERA FORMATION TYPE SECTION:** 5. Interbedded clay and clayey very fine sand in very thin millimetric laminae. Sand very well sorted and rounded, grades down to 6. 0.70 m. **Lacustrine.** 6. Laminated yellowish grey to green clay with silt laminae. 0.30 m. **Lacustrine.** 7. Thin, platy, charophyte limestone, consisting of *Chara* tubules, rare *Coxielladna* gastropods, interbedded with clay as above and below. 0.40 m. **Saline lake, probably ephemeral.** 8a. Brittle, soft, waxy clay, distinctly laminated and thin-bedded, each lamina grades up to fine silt with *Chara* oogonia and ostracods. As for 6. 0.10 m. **Lacustrine, possibly seasonal.** 8b. As above, but oxidised brown, lamination not clear, grades abruptly to red sandy clay with reworked dolomite granules at base. 1.30 m. **Lacustrine, lag preserved at base. NAMBA FORMATION:** 9. White dolomite, thin bedded, hard, micritic, clayey. Very sharp erosional contact at top. 0.10 m. **Lacustrine.**

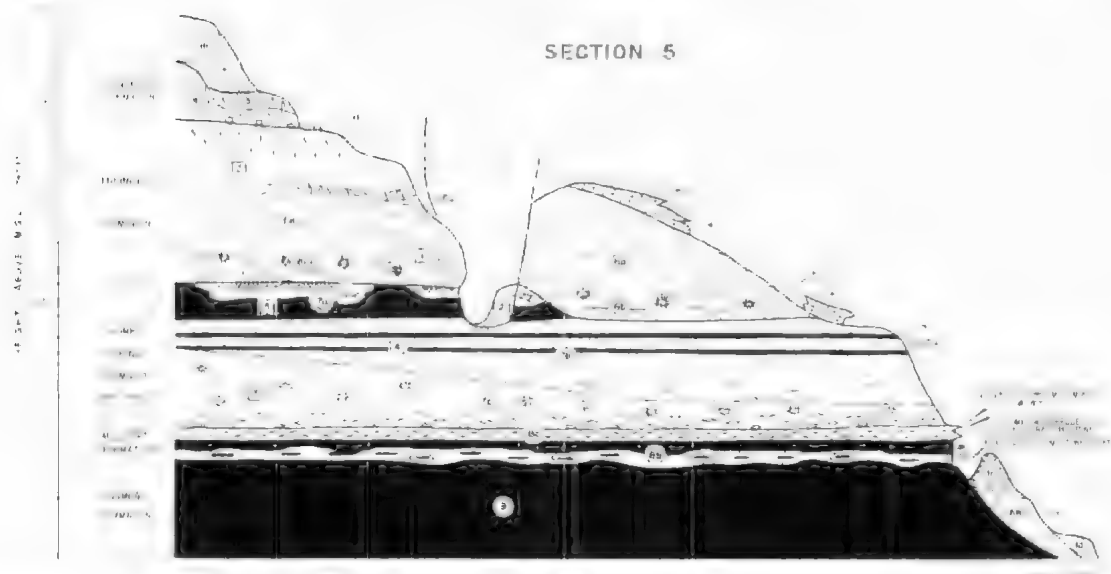


Fig. 4. Lake Millyera, section 5, includes Coombes Springs Formation type section.

1a. Brown sand, 0.30 m. **Modern ephemeral beach and fan deposits.** 1b. Red brown loose fine to medium sand, 3.50 m. **Modern longitudinal dunes.** 1c. Brown to red fine cross-bedded sand 1.00 m. **Modern copse dunes around shrubs.** 2. Red brown sand, fine to medium, poorly sorted. Blocky ped structure 10 × 5 cms. 0.50 m. Slope wash and drift sand. **COOMBES SPRINGS FORMATION SUPPLEMENTARY SECTION:** 3. Light brown sand as for 4, weak diffuse carbonate crust. Blocky polygonal joint pattern. 0.40 m. **Longitudinal dunes with weak palaeosols.** 4. Red brown well sorted, well rounded orange-brown sand, massive. Soft white carbonate mottles at top. 0.60 m. **Longitudinal dunes with semi-arid calcareous palaeosol.** 5. Porous *Chara* oogonia and algal platelet limestone with rare coarse sand and gastropods. 0.20 m. **Probably windblown from nearby beach—suggests ephemeral lake in vicinity.** **EURINILLA FORMATION SUPPLEMENTARY SECTION AND PINPA PALAEOSOL:** 6a, b. Fine to medium sand, poorly sorted, massive light brown sand grades down to medium brown sand with convex large scale false-bedding dipping towards Lake Millyera. Pinkish irregular carbonate nodules in upper part, and capped by several well-developed calcareous rhizonodule and gypsum mottle horizons (Pinpa Palaeosol). Some carbonate granules. **Sand lunettes with some clay pellet layers, capped by calcareous palaeosols (semi-arid).** Shell and *Chara* oogonia lenses in centre. **Windblown shell from nearby beach.** Basal part of section contains clay pellet layers interbedded with small-scale cross laminated coarse sand rich in *Chara* oogonia (tangential bottomsets, foresets face away from Lake Millyera) and rare gypsum sand grains, impregnated with gypsum. 8.00 m. **Gypsum and clay lunette.** **Cross lamination probably represents upward migrating megaripples on aeolian dune front. Seasonally flooded pan.** **COOMBES SPRINGS FORMATION TYPE SECTION** 7a. Hard pale olive clay with irregular shiny ped surfaces, mangans and ferrans well developed. Reticulate gypsum cylindroids truncated in surface. Orange brown patches. Upper contact sharp, flat, eroded. Grades down to light green soft clay interbedded with fine white sand rich in *Chara* oogonia. 2.50 m. **Lacustrine deposits capped by lake mud gypsum of lowered water table. Eroded lake bed.** 7b. Yellowish grey silt to fine sand with numerous thin clay lamellae rich in *Chara* tubules like those in platy limestones of Millyera Formation. Some very coarse lenses. Good sorting and well rounded. Clay pellet layers (coarse). 10 cm thick small scale cross-bed sets. Fish vertebrae, rare egg-shell at base, *Coxielladella* and similar gastropods, ostracods. 5.00 m. **Beach sands of saline lake with permanent water lacustrine phases.** 7c. Bright red brown very fine sand, grading to above unit. Very coarse sand to granules at base. Contact with underlying unit irregular. Massive gypsum rosettes with disc shaped crystals. 0.93 m. **Aeolian source, but fluvial overbank deposits, or playa margin fans? (lacking lamination, mud drapes and mud cracks).** **Saline groundwater horizon.** **MILLYERA FORMATION SUPPLEMENTARY SECTION:** 8a. Rippled to nodular gypsum laminae in red sand as above. Some interbedded charophyte limestone to southeast of main section. *Chara* oogonia and single coarse sand grains scattered through gypsum. **Playa lake with some aeolian content. Ephemeral.** 8b. Yellowish orange to greenish white sand, fine grained, with *Chara* oogonia, very coarse laminae. Reworked distorted clay fragments at base on hard cracked surface. 0.70 m. **Lake or beach sands.** **NAMBA FORMATION:** 9. Hard black clay with greasy skew plane surfaces. Disturbed upper contact. 3.28 m. **Bioturbated lake and swamp deposits. Palaeosol.**

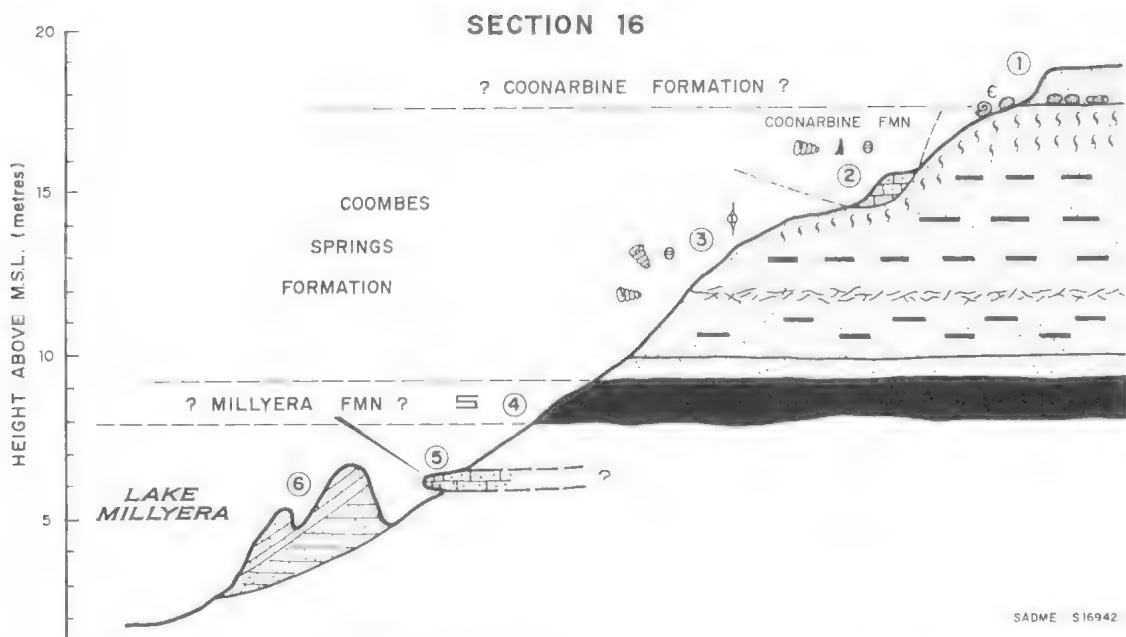


Fig. 5. Lake Millyera—Section 16. (Section "100 m NW section 5" of Callen *et al.* 1983).

?COONARBINE FORMATION: 1. Coarse, orange-brown sand with egg shell, landsnails, algal and root tubules, aboriginal artifacts. 1.10 m. **?Aeolian dune.** 2. Limestone of large *Chara* oogonia and algal platelets. 0.25 m. **?Aeolian—blown from nearby beach—implies seasonal lakes.** **COOMBES SPRINGS FORMATION SUPPLEMENTARY SECTION:** 3. Well sorted medium grained beach sand with no shell over alternating green and brownish green clay and clean white sand with much shell (*Corbicula*, *Coxielladda*, etc). Persistent thin layer of ornamented spiral gastropods. Bedding diffuse and disturbed. Lenses of bioturbated beach sand. Greenish yellow colour. Mottled with white soft carbonate of calcareous palaeosol. 8.4 m. **Beach deposits, with some ?aeolian clay pellet layers. Saline to fresh lake. Semi-arid soil-carbonate cap. MILLYERA FORMATION:** 4. Laminated clay very similar to Millyera Formation. 1.20 m. **Lacustrine.** 5. Hard platy *Chara* limestone, possibly Millyera Formation. As float. **Ephemeral lake. HOLOCENE:** 6. Copse dunes. 1.0 m. **Recent aeolian sand accumulated around shrubs.**

Formation. The beach deposits are mappable as a lithostratigraphic entity, though consisting of a number of separate phases. These phases are grouped into the Coombes Springs Formation, which now includes the upper part of the Millyera formation in some of its former supplementary sections.

The Millyera Formation type section (section 4, Figs 2, 3) has been correlated with a supplementary section (Section 5, Figs 2, 4, 7) using platy charophyte limestone as a marker unit. A persistent bed of laminated, rippled powdery gypsum is found interbedded near the base of the section (Fig. 4) and in a gully to the south; laminated *Chara* limestone is interbedded with this. Between these two sections, the limestone is found at several locations as float (Fig. 2). In addition, laminated green clay like that of the Millyera Formation was found beneath beach deposits at section 16 (Fig. 5), and interbedded with the limestone in section 5 (Fig. 4).

The beach deposits above the limestone and green clay can be traced between sections 5 and 16, but the relationship with section 4 is not seen. Nor is

it known whether they are composite beaches or represent single episodes of stable lake levels.

In Section 17 (Fig. 6), not previously published, beach deposits of similar aspect are found resting directly on the Millyera Formation, which is identified here by the interbedded charophyte limestone and clay. The fine red sand beneath the Millyera Formation in section 5 (bed 7c, Fig. 4) has been found in the vicinity of section 17 (Fig. 6), but definite relationships were not observed. Clasts of this material are in bed 5, and the soil developed on it closely resembles the Pinpa Palaeosol (Callen *et al.* 1983) found on the Eurinilla Formation (bed 6a) at section 5, all of which suggests it could be equivalent to or older than the beach deposits at section 17 (Figs 6, 7). This red sand is topographically higher than the beach deposits at this site, and also crops out along the northern edge of Lake Millyera, where it rests on the Namba Formation. There remains the possibility that the beach deposits of section 17 (Figs 6, 7) are cut into this unit. Thus, although section 17 bed 7 is confidently equated with the Millyera Formation at section

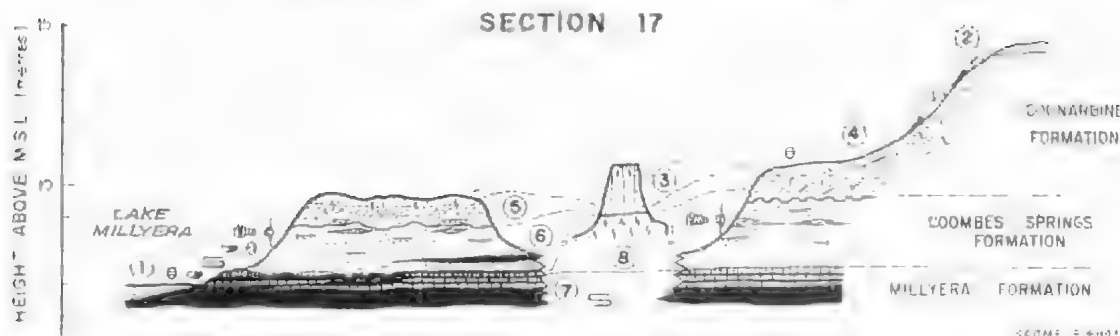


Fig. 6. Lake Milliyera—Section 17.

1. Brown fine sand, 0.30 m. Modern lake, marginal small-scale fans. 2. Yellowish fine to medium loose sand, 7.0 m. Modern longitudinal and transverse dunes. COONARBINE FORMATION: 3. Light brown quartz sand with polygonal joint patterns and weak calcareous patches at top, 1.0 m. Transverse dune and interdune deposits with semi-arid palaeosol. 4. Fine brown quartz sand to brownish grey gypsaeobanite, large-scale cross-bedding at low angle (10–15°). Polygonal joints 40–50 cm across, small gypsum stringers. Numerous *Chara* oögonia. Surface littered with land snails, aboriginal artifacts. Very irregular lower contact. 7.0 m. Transverse sand and gypsum dunes of leeward mounds along east side of L. Frome. 5. Coarse sand with large clasts of underlying beds and bed 8. Much disrupted by rabbit burrows. Calcareous patches at top, 0.90 m. Probably interdune flat deposits. COOMBES SPRINGS FORMATION SUPPLEMENTARY SECTION: 6. Light greenish brown to light brown medium to very coarse sand, becoming clayey and laminated in lower half. Lenses of gastropod and shell in upper part. Fragments of egg shell, scattered fish bones, numerous *Chara* oögonia and ostracods. Some lenses of green clay. Small-scale cross-lamination. Upper surface very irregular, 1.50 m. Lacustrine beach and nearshore deposits. MILLYERA FORMATION: 7. Laminated light green soft clay, sub-conchoidal fracture, with laminae of *Chara* tubules. Pitrid upper contact. Ostracods present, 0.30 m. Lacustrine, offshore, becoming ephemeral at top. COOMBES SPRINGS FORMATION: 8. Bright brownish red fine sand with strongly developed white carbonaceous and gypsum patches. Relationship to 6 uncertain. 2.0 m. Overbank deposits or lake-edge fans with semi-arid soil horizon at top.

5, it is not certain whether the beach deposits above it are equivalent or represent a younger and distinct beach. Added to this is the problem that extensive pedogenesis has taken place on bed 10 of section 5, far in excess of anything encountered on the Milliyera Formation elsewhere (though it may have been eroded).

For these reasons and practical mapping considerations, the Milliyera Formation has been redefined to exclude the beach deposits, which are now grouped into the Coombes Springs Formation. Within these units, considerable complexity is to be expected, along the lines of the model (Fig. 8), which demonstrates a repetition of facies of differing ages. The new use and first publication of the new name are in Callen *et al.* (1983).

The Milliyera Formation is redefined to exclude Units (3–5) of section 5 (Fig. 4), Units 5–7 in the type section 4 (Fig. 3) and all the Milliyera Formation of sections 6 and 7 in Callen & Tedford (1976), which are now included in the Coombes Springs Formation. Unit 1 of the type section (Fig. 3) has been extended downward by means of an auger hole, which intersected Namba Formation dolomite.

Age of Units

The radiocarbon age of calcareous palaeosols has been discussed in Callen *et al.* (1983) for Section 5 (Units 2, 4). Results suggested a "last glacial" age

for beds 3 and 4 of the longitudinal dunes (Fig. 4), and that the Eurinilla Formation lunette is at least 95 000 yrs old.

Section 4 (Fig. 3) was sampled by J. M. Bowler (pers. comm. 1981) for magnetic reversal stratigraphy, and has been determined as magnetically normal throughout. However, it is not known whether this is the Gauss or Brunhes episode. The degree of induration suggests the younger age is correct. Thus the Milliyera Formation is probably between 95 000 and 2.2 million years old, and the Coombes Springs Formation at the type section is probably also within this time episode but younger.

Correlation based on gross lithological and faunal similarities suggest the Coombes Springs Formation overlies the Milliyera Formation, though it is possible the relationships are more complex. For the present, the simpler explanation is accepted. Height differences between sections are within the limits of the barometric method used (± 1.5 m).

All units are younger than the Namba Formation (Callen & Tedford 1976) which may extend to late Miocene age or even Pliocene in the upper part.

Discussion and Interpretation (Fig. 7)

Although the detailed relationship between these sequences has not been fully resolved, the follow-

CLIMATIC SUMMARY
(Based mainly on Section 5)

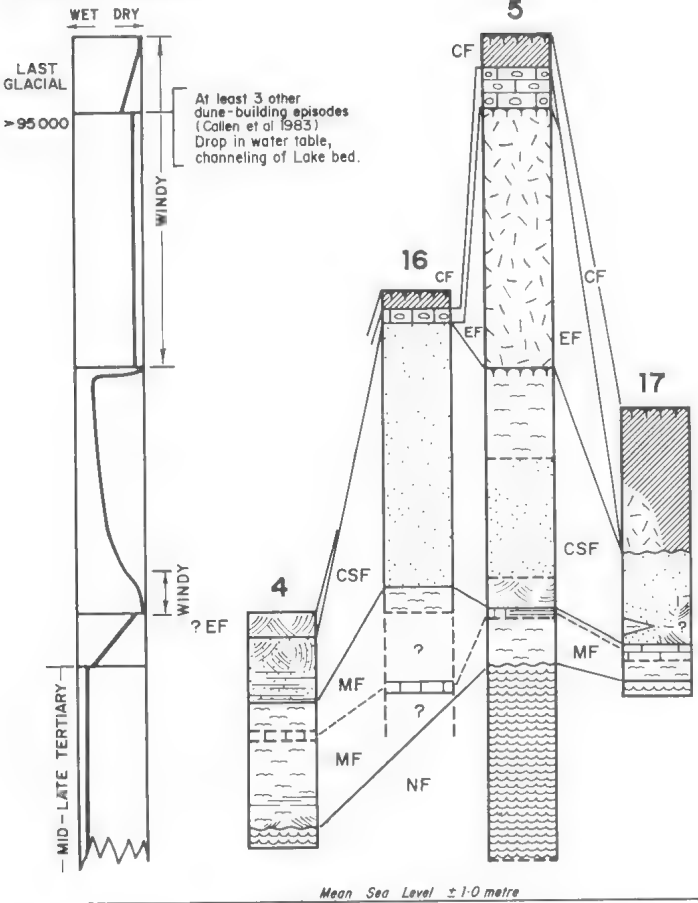


Fig. 7. Lake Millyera. Correlation of sections and environmental/climatic interpretation.

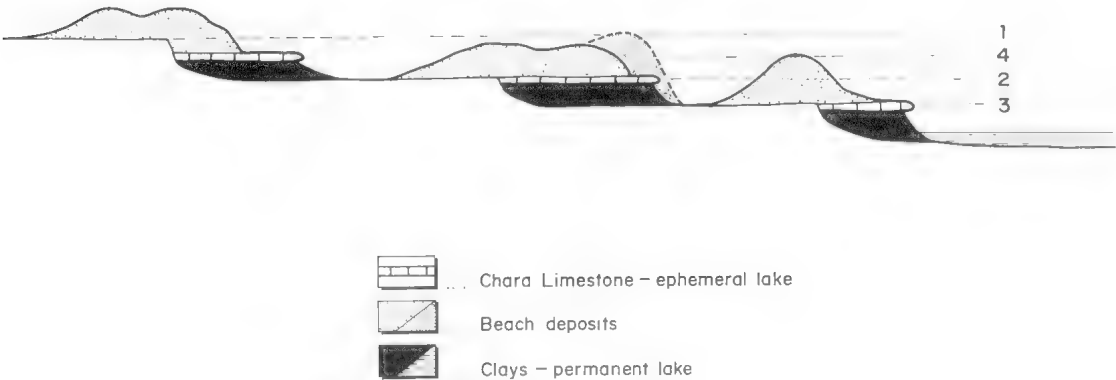


Fig. 8. Diagram of beach and lacustrine facies for a shallow lake of fluctuating depth. 1-4 are successive lake levels.

ing comments can be made, and are summarized in the Figure captions (Figs 3–6). They supplement and modify the outline given in Callen (1977, pp. 164–5 and Fig. 6) and Wasson (1983a, b).

Deposition in the Lake Millyera region in post-Namba Formation times (Late Tertiary or after) began with the lacustrine Millyera Formation. The deposits have features indicative of a standing body of saline water. They are finely laminated green clays, with increasingly abundant calcareous algal laminae near the top (stem moulds and fruiting bodies of charophytes). The clays contain ostracods, including *Reticypirus kurdimurka* (pers. comm. P. De Deckker 1983), and rare spiral gastropods. Charophytes can reproduce in salinities up to twice that of seawater, but may require lower salinities for germination of zygotes (Burne *et al.* 1980). The algal limestone beds grade into rippled gypsum, a relationship observed in modern environments nearby (Callen & Tedford 1976), and showing the water was highly saline in the final depositional phase and at least some of the time during clay deposition.

These sequences suggest a permanent lake as there is no evidence of drying and palaeosol formation during clay deposition. The proportion of carbonate laminae increases upwards over about 50 cm and terminate abruptly, suggesting increasing salinity variations and drying of the lake. There followed a brief return to a permanent lake before the watertable dropped and the shoreline of this precursor of Lake Frome retreated west of Lake Millyera.

As the lake dried, coarse aeolian sand grains were blown onto the gypsum deposits. This was followed by deposition of horizontally laminated red-coloured fine sand as the lake regressed, probably representing an ingress of waterborne aeolian sediment to the lake margin. At this time the lake shrunk to near its present shoreline. The red sands are an early phase of the Coombes Springs Formation. They are cemented with large disc-shaped gypsum crystal rosettes, deposited from saline groundwater in subsurface. Although indicating a drop in watertable, this was still much higher than present.

The red sands were followed by fine white to greenish sands rich in fossils. They contain an abundant shelly fauna, dark-coloured smooth eggshell, fish remains, and calcareous *Chara* algal remains. The gastropods and bivalves include *Coxiella*, *Coxielladda*, *Potamopyrgos*, *Corbicula* and *Pisidium* species, all of which are salinity tolerant, though not of high salinity like that in present day desert salt lakes of this area (Buonaiuto 1982¹). The beach deposits resemble those of modern Lake

Eyre formed in recent times, though with a more diverse shelly fauna. The comparison suggests a great potential for bird fossils.

Higher in this sequence are massive alternating green clays and sands. The clays, though massive and rather crumbly, do not exhibit aeolian clay pellets, though containing rounded clay-flakes indicating exposure of mudflats. Some of this structure is probably the result of soil processes. Slickensided skew planes with clay and iron oxide coatings are common. These sediments are interpreted as lake deposits affected by later soil processes. The soil is best developed at the top, where a reticulate mass of gypsum penetrates the clay bed, and has been truncated at the surface. Thus pedogenesis took place on a former lake bed, implying the watertable dropped beneath the lake floor. This lake bed forms the foundation to the extensive sand-covered flats in the vicinity.

Elsewhere, along Lake Tarkarooloo, the Coombes Springs Formation can be traced laterally into brown fluvial cross-bedded sands and gravels (Callen 1977), cemented with carbonate. These deposits are in channels cutting into the Namba Formation and contain abundant burrows, possibly of insects such as ants (Callen & Tedford 1974, Callen 1977).

Lunette dunes of the Eurinilla Formation were built upon the lake bed near Lake Millyera. These are essentially sandy, but have clayey layers with up to 40% aeolian clay pellets at the base, alternating with cross-bedded sands. This small scale cross-bedding dips away from the lake, whereas the dominant low angle large scale crossbeds dip towards it. The small scale crossbeds were probably formed by lee eddy deposits. The base of this section is impregnated with secondary gypsum, and occasional rounded gypsum grains are present, suggesting there may have been more abundant aeolian gypsum previously. The sands are rich in charophyte oogonia and contain occasional shelly layers, suggesting periodic flooding of the surrounding lake floor. The sequence is capped by calcareous palaeosols, demonstrating stabilization of the dunes, and the presence of rhizomorphs indicates growth of plants. Rare *Diprotodon* tooth enamel fragments and *Genyornis* and emu eggshell are present. Similar deposits are present along Billeroo Creek and at Lake Moko, but no clay pellets were identified.

The origin of clay pellet dunes and building lunettes has been adequately discussed by Bowler

¹Buonaiuto, J. M. (1982) Late Cainozoic non-marine mollusca of the Lake Frome area and other selected localities from northeastern South Australia. *S. Aust. Dept Mines & Energy Rept*, 81/68 (unpublished).

(1983), and for Lake Frome, by Callen (1983). Clay is broken down on mudflats where groundwaters periodically reach to the surface, permitting crystallization of salts and "fluffing" of clay, which is then blown off the dry lake bed. Gypsum is broken down into cleavage flakes and blown into dunes; rounded edges and sorting are evidence of wind transport.

Elsewhere the Eurinilla Formation is essentially fluvial, with shallow ephemeral streamflow (Callen & Tedford 1976, Callen *et al.* 1983). Some redbeds mapped as this unit on the FROME geological sheet are likely to be aeolian, or fluvial equivalents of the Coombes Springs Formation. The temporal relationship between the aeolian and fluvial facies in the Eurinilla Formation is uncertain. The streams cut down into the older lake deposits, and the shoreline of Lake Frome regressed to its present location. The channels contain locally abundant vertebrates similar to those at Lake Callabonna.

Thus there was a profound drop in water table, suggesting a significant decrease in rainfall. The absence of extensive aeolian deposits suggests lack of windiness, though deposition in many desert terrains tends to be dominantly fluvial, and other aeolian facies may yet be recognized.

Longitudinal dunes were built upon all of these sequences, recording a change to aeolian conditions, and increased windiness. However, the abundance of clay pellets in these dunes indicates periodic flooding of the interdune corridors, so the water table was still higher than present (Callen *et al.* 1983, Wasson 1983a, Ash & Wasson 1983). The pure algal oögonia limestone beds suggest Lake Millyera was flooded quite regularly.

Conclusions

The catena of landforms described above has been controlled by a fluctuating watertable and ultimately by climatic change. The cycles begin with a permanent brackish lake extending east of present day Lake Frome. This lake became ephemeral, decreased in size, and semi-arid conditions prevailed, though watertables were much higher than present (10 m or more). Processes were dominantly fluvial and lacustrine, though there is some evidence for wind-blown material. This lake expanded again, and a shoreline was established in the vicinity of Lake Millyera. Following subsequent development of full lacustrine conditions, the lake finally dried, and the watertable dropped well below the lake floor.

Lunettes developed on this old lake bed, recording the demise of permanent long term lakes in the region. The Billeroo Creek found its way through the barrier of aeolian and beach deposits, and cut down into the lake floor. Although runoff and sediment load appear greater than at present, aeolian deposition became a prominent feature. These deposits record a major drop in watertable indicating a significantly drier climate was established between about 0.1 and 2 million years ago.

The last cycle of events records the building of the longitudinal dunes and origin of the Strzelecki Dunefield, though this is better recorded elsewhere (Callen *et al.* 1983) in the region, only the later phase being present at Lake Millyera. This represents the effects of the last major glaciation, an event abundantly recorded throughout southern Australia (Bowler *et al.* 1982, Wasson 1983b). These dunes indicate strong directionally variable winds from a narrow westerly sector of the compass, a higher watertable than present, rather limited sand supply and more arid climate (Wasson 1983a, Wasson & Hyde 1984).

At present, dune building is still active, though flooding of interdune corridors and formation of clay pellets is rare. Quartz sand dominates the dunes. Fluvial sedimentation on this side of Lake Frome is restricted to clays in suspension and locally reworked aeolian sand. Downcutting has been limited by failing streamflow and a hard sub-surface in the form of the dolomite of the Namba Formation. Lake Frome very rarely fills to its present shoreline.

Thus is recorded the demise of permanent brackish lakes in the northeast of South Australia, and development of an increasingly arid climate though with periodic fluctuations, at least partly due to world glaciations. Aeolian processes and ephemeral watercourses are now dominant.

Acknowledgments

Dr J. M. Bowler (Research School of Pacific Studies, A.N.U.) assisted under the SLEADS programme in trenching on section 16, and provided palaeomagnetic data for section 4.

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Note added in proof

Coombes Springs should read Coomb Spring, based on latest information from S. Aust, Dept of Lands. The new rock unit name is, therefore, Coomb Spring Formation. The location of section 5 is 31°02'59", 139°56'36", not as given in Callan & Tedford (1976).

MURPHY HAYSTACKS, EYRE PENINSULA, SOUTH AUSTRALIA

BY C. R. TWIDALE & ELIZABETH M. CAMPBELL

Summary

Murphy Haystacks consist of two groups of large residual granite pillars and boulders located near the west coast of Eyre Peninsula, between Port Kenny and Streaky Bay. Many of the pillars and boulders have flared sidewalls and several are partly hollowed out through the development of tafoni. The gross forms were in existence at least by the later Pleistocene though there has been some slight further exposure during recent times. The pillars and boulders could be derived from the differential subsurface weathering and exposure of large cubic or quadrangular blocks defined by orthogonal joint sets. Alternatively they could be remnants, again modified by subsurface moisture attack, of massive convex-upwards sheets of rock. Which of these possible origins applies to Murphy's Haystacks cannot be unequivocally demonstrated, but on balance the evidence favours the second theory.

MURPHY HAYSTACKS, EYRE PENINSULA, SOUTH AUSTRALIA

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Summary

TWIDALE, C. R. & CAMPBELL, E. M. (1984) Murphy Haystacks, Eyre Peninsula, South Australia. *Trans. R. Soc. S. Aust.* 108(3), 175-183, 13 December, 1984.

Murphy Haystacks consist of two groups of large residual granite pillars and boulders located near the west coast of Eyre Peninsula, between Port Kenny and Sreaky Bay. Many of the pillars and boulders have flared sidewalls and several are partly hollowed out through the development of tafoni. The gross forms were in existence at least by the later Pleistocene though there has been some slight further exposure during recent times. The pillars and boulders could be derived from the differential subsurface weathering and exposure of large cubic or quadrangular blocks defined by orthogonal joint sets. Alternatively they could be remnants, again modified by subsurface moisture attack, of massive convex-upward sheets of rock. Which of these possible origins applies to Murphy's Haystacks cannot be unequivocally demonstrated, but on balance the evidence favours the second theory.

KEY WORDS: Pillars, granite forms, Eyre Peninsula.

Introduction

It is said that when coachmen on the old Sreaky Bay-Elliston-Port Lincoln run reached a point a few kilometres NW of Port Kenny, they used to point out to their passengers a group of large residual granite pillars and boulders standing on the skyline near the crest of a hill, and which look like the upper halves of hourglasses. Not unreasonably they likened them to haystacks or hayricks, and as they stood on the Murphy property they became known as Murphy's Haystacks. The name has endured, partly because of its origin in the romantic (if uncomfortable) days of the horse and carriage, but also, it is suggested because the name is as descriptively apposite as can be found in the English language (see below).

Located in the Calca district some 25 km NW of Port Kenny and 35 km SE of Sreaky Bay (Fig. 1), Murphy Haystacks (Fig. 2) are a well known local landmark. They are becoming internationally known in the popular literature because of their odd name, large size, intricate sculpture, and intrinsic beauty.

The Haystacks offer many points of interest, including the origin of the gross forms. Although some of the residuals are free-standing, most are apparently contiguous projections of the granite that underlies the hill on which they stand, and the questions arise as to whether the nature of these subsurface extensions are modified projections of quadrangular blocks or exposed portions of spheroidally weathered kernels or coresones (Fig. 3), and whether the forms are derived from a mass of granite dominated by orthogonal fracture sets or by arcuate, convex-upward sheet struc-

ture. The intricate sculpture of the Haystacks may be due to subsurface weathering or to epigene attack. Answers to these questions are fundamental to a debate concerning the origin of large residual boulders and related forms (see Linton 1955; King 1958; Twidale 1982). Orthogonal fractures are due to shear stresses and reflect regional tectonic style (Cloos 1936), whereas arcuate convex-upward sheets are variously interpreted as due to erosional off-loading (Gilbert 1904), or to lateral compression that is genetically related to crustal stress (Twidale 1964, 1973, 1982).

Description

The Haystacks consist of two areally separate though genetically related groups of pillars and boulders standing near, though not on, the crest of a convex-upward roughly circular hill. They are about 40 m above the adjacent valley floors and 100 m a.s.l. (Figs 1 & 4). The granite from which the residuals are shaped is a pink, massive, coarsely equigranular rock consisting mainly of quartz and orthoclase. Similar granites near Baird Bay and on the Investigator Group islands near Elliston are of Middle Proterozoic age and 1456 ± 26 Ma old (Webb *et al.* 1982¹). The crest and flanks of the hill however, though eroded in granite, carry a veneer of calcrete, a pedogenic limestone that in the area under discussion is derived from dune calcarenite or aeolianite (Crocker 1946) and carbonate dust.

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¹ Webb, A. W., Thomson, B. P., Blissett, A. H., Daly, S. J., Flint, R. B. & Parker, A. J. (1982). Geochronology of the Gawler Craton, South Australia. *Dept. Mines & Energy, South Australia, Rept. Bk. No. 82/86* (unpubl.)

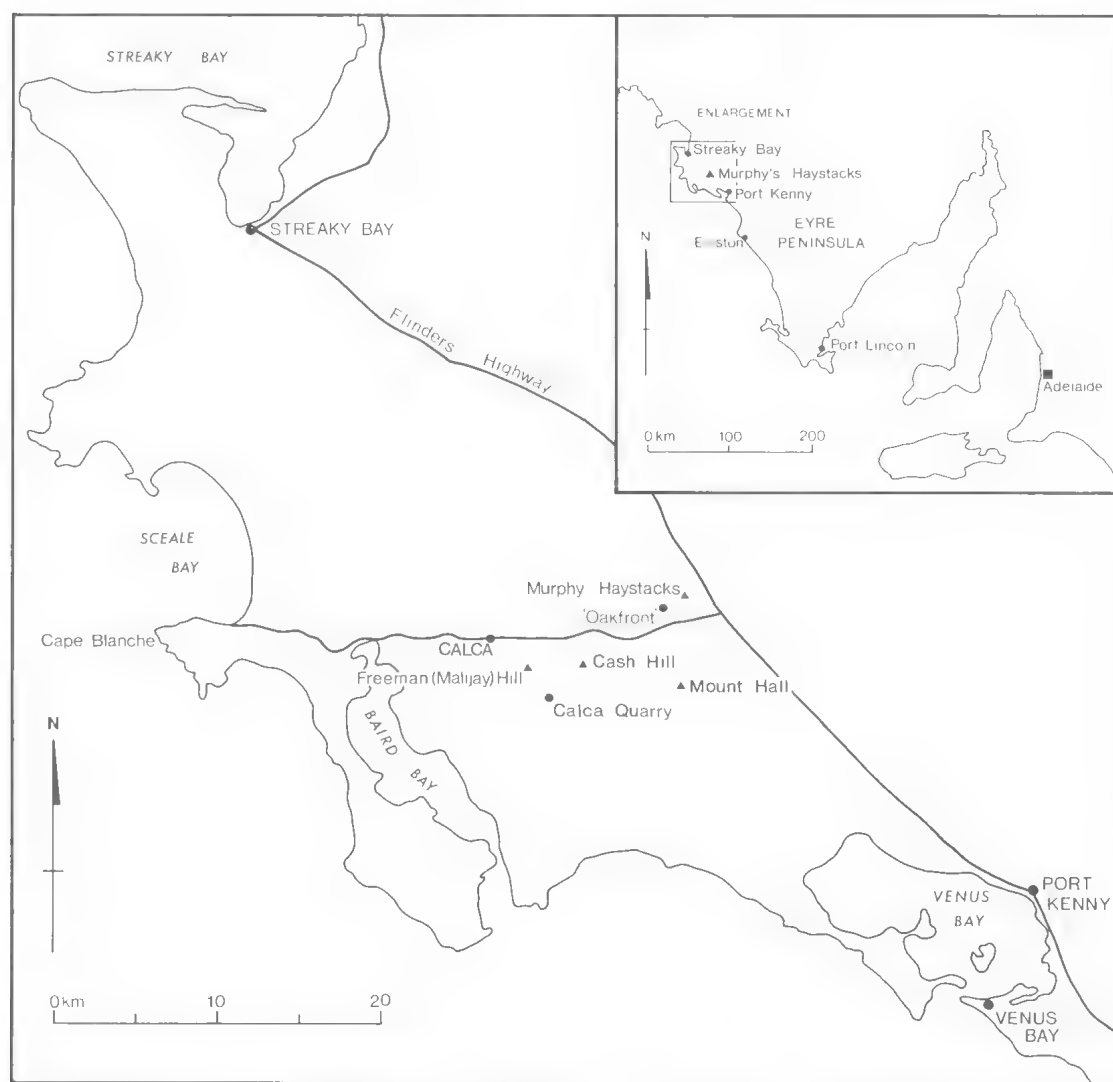


Fig. 1. Location map.

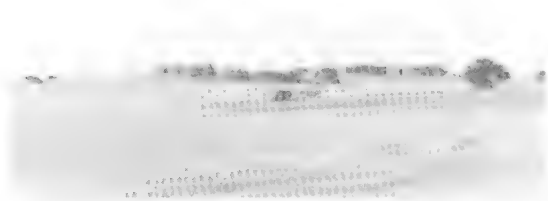


Fig. 2. General view of Murphy Haystacks (eastern group) seen from the east (Port Kenny—Streaky Bay road).

The term 'boulder' is suitable for those rounded masses that are wholly exposed and detached but it cannot be used of the many others that merge unbroken with the underground rock mass. They seem to be attached to a solid cohesive base but,

as stated previously, it is not known whether they merge with the base of a corestone or with an essentially unaltered block (Fig. 3). In this circumstance it is preferable to use a descriptive and non-genetic term, and it is suggested that the apparently attached forms be called 'pillars', used in the sense of upright columns, and additionally to borrow the colloquial term 'haystack' for those pillars with sidewalls so flared that they widen appreciably from the base to the upper shoulder.

Both groups of pillars and boulders are of King's (1958) "skyline" type for though they are not on the crest of the hill, they stand high on the convex-upward sideslopes. The eastern group is smaller than the western, but the two comprise similar suites of forms. Both consist mainly of large pillars up



Fig. 3. Alternative explanations of haystacks: (a) boulder (i) and pillar (ii) derived from granite dominated by orthogonal fracture sets; (b) boulders and pillars from granite subdivided by arcuate, convex-upward sheeting joints.

to 10 m high and characteristically with flared sidewalls (Fig. 5). Some, and two in the eastern group in particular, have well developed tafoni, or hollows. One of the two is noteworthy for its sheer size (Fig. 6), the other because vertical grooves (*Rillen* or *Karren*) are faintly developed on the overhanging inner wall of the hollow. Some of the boulders are similarly modified, and one of the large boulders in the western group displays both flares and a large tafoni with ribs protected by heben. Less common are blocks that have been only slightly modified by weathering, giving rise to tabular forms.

These pillars, boulders and blocks are the basic forms but there are many variations, combinations and modifications. One pillar in the eastern group is tall and narrow and resembles an hourglass. Some little-rounded blocks stand squarely one upon the other to form cottage loaves. Some blocks have sidewalls so weathered and flared that quite wide platforms are developed around their bases, and in extreme cases the platforms are so wide and the central pillars so reduced in height as well as diameter that the whole looks like a boss and shield (Fig. 7). With further weathering the pillar has been wholly eliminated to produce a platform flush with the ground surface (Fig. 8). Many of the blocks and pillars retain secondary fractures within their masses, and many carry detached shells.

Though apparently haphazard in their distribution, mapping shows that many of the boulders are partly defined by fractures (Fig. 4). Moreover many are in plan disposed in orderly fashion with respect to intersecting fracture sets. In the eastern group the major fractures trend SSE-NNW (135° - 160°) and NNE-SSW (20° - 25°), with an east-west set also present. In the western group however the form and disposition of the residuals are related to two inter-

secting arcuate sets disposed in radiating fan-like patterns with axes trending roughly east-west and SW-NE (Fig. 4).

Age of the Forms

The plains and slopes separating and surrounding the granitic residuals are covered by a veneer of calcrete derived from calcarenite (the aeolianite or dune sand of Crocker 1946) and carbonate dust. Though in many places wash from the residuals has caused the calcrete to be dissolved, creating annular depressions around the bases of the pillars and haystacks (cf. Jennings 1973), the calcrete essentially laps up against the bases of the forms. Moreover at one site calcrete with fossil foraminifera fragments occurs within a hollow formed along the joint that cuts through the base of the residual. This limestone and one from nearby Freeman (Malijay) Hill have been dated by the C14 method (GaK-5266 and 5267) as of late Pleistocene age (Twidale *et al.* 1976). Thus there is the suggestion that the Haystacks were essentially in existence before the Pleistocene dune calcarenites and pedogenic calcretes. Some of the minor as well as the gross forms have been exhumed from beneath the dune cover (cf. Jack 1912).

Many blocks and pillars stand on low plinths, whose pitted surfaces indicate recent exposure (Twidale & Bourne 1976a). In a few cases calcium carbonate has impregnated the granite exposed at the bases of the residuals. This pitting and the steep-sided, lowermost slopes of the pillars (Fig. 9) argue recent exposure through soil erosion of approximately 25 cm (probably following clearance of vegetation by European settlers, followed by ploughing and pastoralism), but the gross forms of Murphy Haystacks predate the late Pleistocene carbonates and can be regarded as partly exhumed from beneath those carbonates.

Origin of the Forms

The problems: Whether the large residuals of Murphy Haystacks are pillars or boulders, the problem of their rounding remains the same. It has long been recognised and accepted that some boulders owe their rounding to abrasion by rivers and waves but, equally, that weathering is differential and causes the conversion of angular to rounded forms. As MacCulloch (1814 p. 76) noted "*Nature mutat quadrata rotundis*": granite blocks have been "rendered spherical by decomposition" as a result of the more rapid attack by moisture on corners and edges than on plane faces. The problems concerning the pillars at Murphy Haystacks are whether the two upper corners of a block have been so rounded or whether all four have been affected (Fig. 3), and whether the fractures exploited are of orthogonal or sheeting sets.

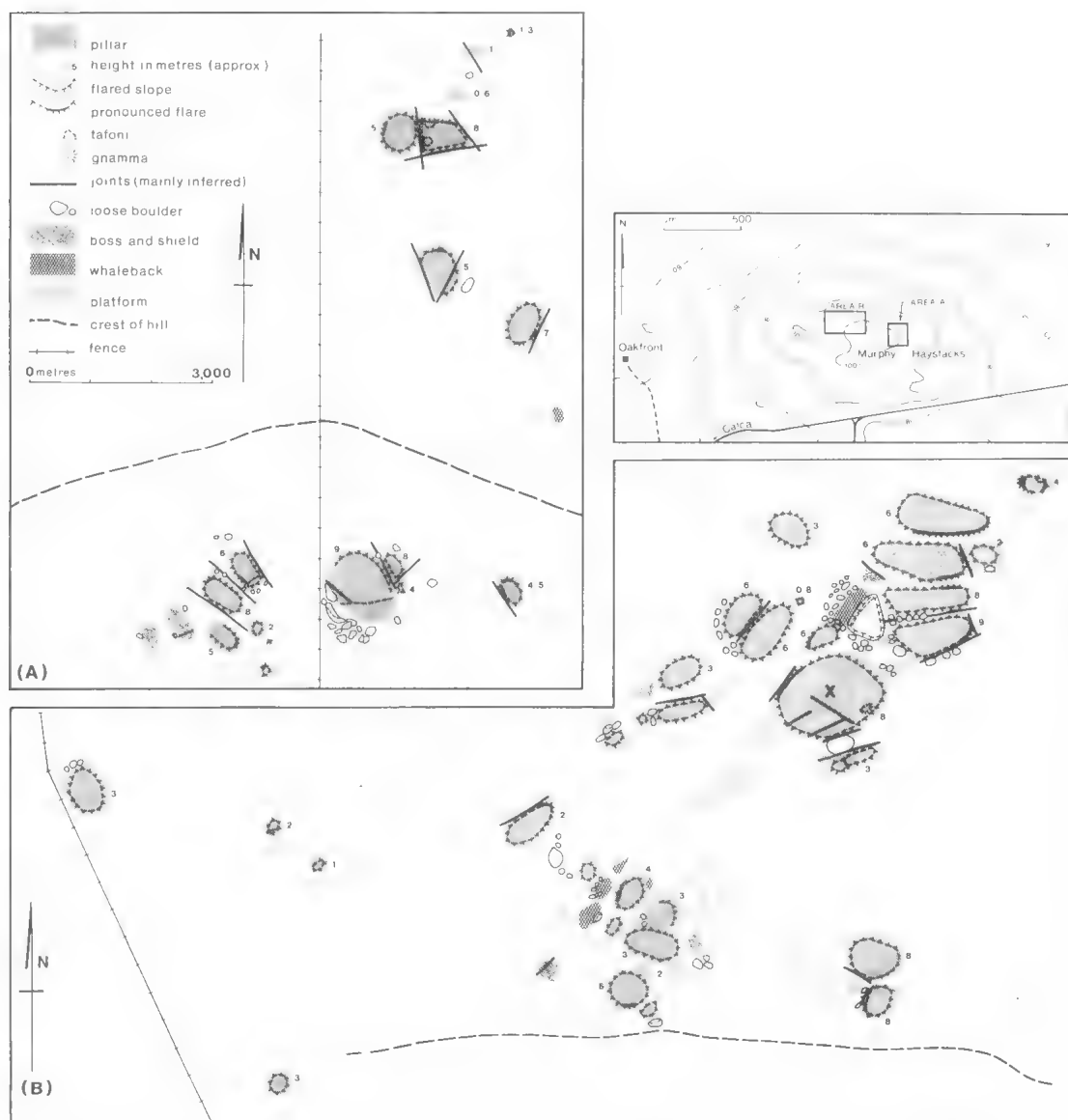


Fig. 4. Plans of Murphy Haystacks, and contour plan of the area showing also locations of plans of eastern group (area A) and western (area B). Contour plan adopted from S. Aust. Lands Dept. 1:50,000 series Calca 5731-1.

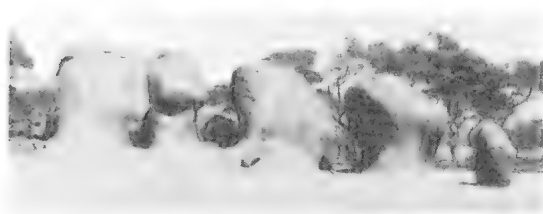


Fig. 5. Prominent haystacks at eastern margin of western group seen from east. Hill crest is to left. Note that flared sidewalls are better developed on upslope (left) side; also isolated horizontal fracture.

The question of whether the weathering took place beneath the land surface as suggested by Hassenfratz (1791) and many others (see Twidale 1978) through to Linton (1955) or after exposure as suggested by King (1958), is readily resolved, for most of the pillars and boulders are in some degree flared.

Flared slopes are a particular form of the weathering front (Mabbutt 1961) which may in general terms be defined as the lower or lateral limit of significant weathering. Flared slopes are best developed in piedmont or scarp foot situations, or



Fig. 6. Large boulder tafone, eastern group.

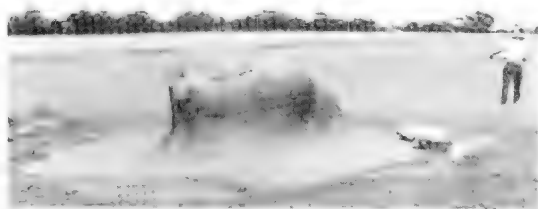


Fig. 7. Boss and shield, eastern group.



Fig. 8. Platform in western group.

along open joints in massive rocks, and in tectonically stable regions (Twidale 1962, 1972); anywhere there is a long-term concentration of water in a rock type that is altered in such a way as to produce an abrupt transition from weathered to unweathered rock. Granite is an eminently suitable medium in most respects. Water running off the hill or large boulder permeates into the rocks at the base of the residual. There, because of water retention, chemical weathering is enhanced. Also,



Fig. 9. Base of flared haystack with narrow platform and steep basal slopes; evidence of recent soil erosion from surrounding plain (eastern group).

because of surface desiccation the weathering front advances laterally more rapidly at depth than at the surface (Fig. 10). Thus when as a result of lowering of the plains the weathered detritus of the piedmont is evacuated, the exposed weathering front is concave in form. The essential feature of this explanation is two stage development, the first consisting of subsurface weathering, the second exposure by erosion. Incipient flares, in the form of concave weathering fronts still beneath the natural land surface have been observed in excavations at Yarwondutta Rock, Chilpuddie Hill and several other sites on Eyre Peninsula (see e.g. Twidale 1962, 1982, pp. 243-257).

The common occurrence of flared sidewalls on the pillars and boulders at Murphy Haystacks shows that the granite blocks on which the forms are based were subjected to weathering beneath the land surface. The moisture attack was directed along vertical and near-vertical joints and the weathering was most effective 6-8 metres beneath the land surface. Some of the tafoni that are evident at the Haystacks may have been initiated in the same manner; they may be flares at which weathering has been especially rapid (perhaps by reason of mineralogical or structural weakness), though there has undoubtedly been development after exposure (see Bradley *et al.* 1978; Twidale 1982).

Orthogonal or Sheet Jointing: Evidence and Argument

The various major forms and some of the more prominent minor features present at Murphy Haystacks have their origin in the shallow subsurface. But what was the structural base: did subsurface moisture attack affect orthogonal or sheeting joints? The exposed residuals vary in size, indicating

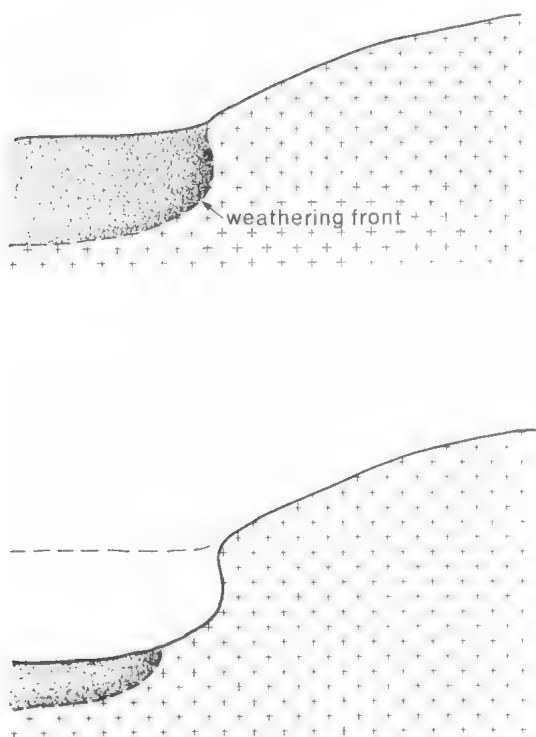


Fig. 10. Development of flared slopes.

either variations in original fracture spacing or in the intensity of weathering, or in both factors. No pattern is evident. The variations are equally, if in rather general terms, explicable in terms either of orthogonal or of sheeting sets. Some arguments and evidence are however diagnostic.

Lack of basal separation: Although some pillars have horizontal or sub-horizontal fractures at or near their bases, most do not: they merge without physical break with the underlying granite. This is equally explicable in terms either of corestone development in the context of orthogonal blocks, or in terms of the weathering of radial fractures developed within sheet structure. No grus, or weathered granite, has been found beneath boulders or pillars, but this may be due to a lack of suitable exposures.

Location on hill: That neither group of pillars and boulders stands on the crest of the host hill may be significant. If the pillars were developed from orthogonal joint blocks the residuals would on the one hand reasonably be expected to survive longest on the crest of the hill, most distant from the erosive effects of rills and streams that before the accumulation of calcrete would have coursed down the slope. On the other hand, the larger corestones might be expected to occur on the lower hill slopes because the deeper zones would not have been sub-

jected to moisture attack for as long a time as those near the surface. Yet in reality the surviving pillars and boulders occur just below the crest. It may be that the orthogonal fracture sets are nonpervasive and are heterogeneously distributed within the hillmass. The hill crest may be upstanding by virtue of such a lack of open fractures. On the other hand the pillars and boulders, though not on the crest are quite close to it. In any case even if the distribution of fractures is uneven, strain patterns, being regional, are not; and such strain zones are as readily exploited by weathering as are fractures. An alternative explanation is that the hill is underlain by sheet structure. In these terms the crestal zone, being antiformal, would be in tension and therefore vulnerable to weathering by water. The arcuate fractures on the other hand allow percolation of water into the synformal (valley) zones that for that reason are deeply weathered, so much so that no corestones or masses of fresh rock have survived. In other words the plan distribution of the pillars is consistent with the sheet structure concept.

Survival of minor forms on crest of residuals: At Caloote, in the eastern piedmont of the Mt Lofty Ranges, some 65 km E. of Adelaide, a rounded granite hill carries several large sculptured granite blocks notable for their roughly flared sidewalls (the



Fig. 11. Residual block with crestal grooves, Caloote.

granite is coarse grained) and the odd shapes that have resulted from subsurface moisture attack. For instance one block is shaped like an anvil, and has preserved on its gently rounded crest a gnamma or rock basin. The crest of another is scored by several parallel gutters that run entirely across the crest (Fig. 11). Such minor forms as basins and gutters are characteristic of the gently inclined slopes of inselbergs cut in massive rock, and remnants of such forms on the crests of pillars and boulders at the site under discussion would point to their being fragments of a disintegrated dome. A search was made of the crests of the pillars and boulders at Murphy Haystacks but only one large squat pillar (X in Fig. 4) has a gnamma developed on its crest, and on the same residual there are two gutters. One is clearly fracture-controlled and can be discounted in the present context. The other is partly controlled by structure (it runs along several discontinuous veins) though it does diverge in places and especially toward the edge of the pillar. But it does not run across the residual, as do those at Calonte, and though it may have had its origin on the more extensive massive sloping surface, it may not. Similarly the rock basin may have evolved on a structurally weak site and does not constitute undeniable proof that the Haystacks are derived from the disintegration of a domical inselberg.

the convex-upward form of the hill is suggestive of determination by sheet structure, and some of the subhorizontal fractures present are associated with triangular wedges that are typically associated with sheet structure (Twidale 1964, 1973, 1982). Similar wedges occur on the crests of some pillars. They are related to differential movement along the sheeting planes and ultimately to the rock masses being in stress (Twidale 1964, 1982; Twidale & Sved 1978). One such horizontal fracture in one of the prominent haystacks of the western group has such triangular wedges on both sides of the residual, that on the northern face being single but those on the southern being complex and in detail consisting of at least six distinct wedges (cf. the complex wedge at Ucontichie Hill; Twidale 1971, p. 71). Such fracture patterns are readily explained by a single phase of differential movement, as are other wedges, but they could reflect vertical pressure.

Flares and aspect: Given a vertical fracture that controls water percolation and the development of flares, all else being equal flare development ought to be similar on both sides of the subsequent fracture-controlled cleft. If however the fractures were inclined, and given that water percolates under gravity, the upslope facing side of the fracture ought to be more weathered and develop a more pronounced flare than that associated with the overhang facing downslope (Fig. 12). If the fracture system that controlled weathering were orthogonal and vertical then there ought to be no preferred distribution of flares. Conversely if the jointing is orthogonal but inclined then flares will be consistently asymmetrically distributed. If on the other hand the fractures are part of fan sets associated with sheet structure then there ought to be contrasted asymmetry on opposed flanks of the hill.

In the field there is a tendency for there to be a greater development of flares on the upslope-facing side of pillars, and for that tendency to be in the reverse aspect on opposite sides of the hill (see e.g. Fig. 5) and though there are many exceptions, and even great variations of flare development on the same aspect on adjacent blocks, there are many assemblages that suggest sheet structure and radiating secondary fractures rather than orthogonal sets.

Evidence from nearby hills: Since fracture patterns in crystalline rocks such as granite are arguably due to regional stress, comparisons with adjacent uplands are relevant to the problem of Murphy Haystacks. Some of the nearby hills offer better exposures of the granite than can be obtained at Murphy Haystacks. Thus at Cash and Freeman hills (Fig. 1) calcrete is preserved on the hill crests

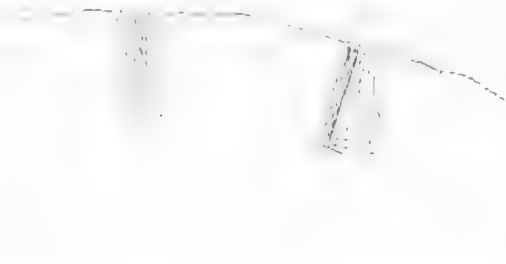


Fig. 12. Preferred development of flares on opposed aspects.

Fractures: If the granite mass beneath the hill were subdivided by orthogonal sets then some horizontal or subhorizontal members ought to be in evidence. Such horizontal fractures as do occur are notably localised, frequently restricted to one pillar and absent from those nearby (see e.g. Fig. 5). The vertical members ought to run in parallel. If on the other hand the hill is underlain by sheet structure the secondary joints in section ought to form a radiating or fan-like pattern. Unfortunately most of the flares are covered by rubble or calcrete and too few joints are exposed for a pattern to be plotted, though some indirect evidence on this point has been deduced (see below). On the other hand

and lower slopes but there are extensive outcrops of granite at midslope. The Calca Quarry also provides excellent exposures of another granite rise. And it is clear from all of these that the granite mass is dominated by arcuate, convex-upward sheet structures, that have disintegrated to give orthogonal blocks. It is notable that at Freeman Hill there are large residual boulders protruding above the late Pleistocene calcrete, though they are neither as large, nor as numerous, nor as intricately sculptured. But these more southerly hills are slightly higher than Murphy Haystacks and possibly did not receive the same thickness of sand cover, so that subsequent erosion has been more effective and allowed extensive exposures of the granite country rock.

The suite of forms at Murphy Haystacks is similar to that which would develop if a domical inselberg or bornhardt like Ucontitchie Hill or Mt Wudinna were partially buried by dune sand, and particularly calcareous sand. Ground water percolating through such material would become alkaline and so more actively attack the granite (e.g. Alexander *et al.*, 1954; Twidale 1979). The crests of Mt Wudinna and Ucontitchie Hill are boulder and block-strewn, but the mid slopes are essentially smooth, being largely an expression of sheet structure. On the other hand, though largely similar, there are important differences in detail between this assemblage and some of those, such as Richardson Rocks, described from the Upper South East (Twidale & Bourne 1975b; Twidale *et al.* 1983). It may be that Richardson Rocks, standing and developed by differential weathering beneath a plain, show water table effects in greater degree, in for instance the common development of low tabular forms.

Conclusion

The groups of large residual boulders and pillars that are Murphy Haystacks stand on the upper slope of a convex hill underlain by granite but with a veneer of calcrete derived from dune calcarenite. Though not conclusive, the weight of evidence and argument suggests that the boulders are remnants of a sheet structure. The massive sheet is subdivided by fan joints. Water penetrated down these, causing the widening of the fracture clefts and the formation of flared slopes on the bounding walls during subsurface chemical weathering. Erosion of the weathered granite or grus allowed exposure of the sculptured blocks. This took place prior to the spread of coastal dunes during the Pleistocene. The dune calcarenite spread far inland and buried not only many of the hills of the Calca district (though it is not known whether the pillars and boulders at Murphy Haystacks were totally overwhelmed) but also a granitic landscape of considerable relief that occupied much of the northwestern Eyre Peninsula. It is clear however, that the calcarenites and calcretes at least lapped around the bases of the residuals. Following an amelioration of climate and rise of sealevel, much of the dune material was eroded, though some was precipitated to form calcrete, and soil erosion of some 25 cm took place, but only the topsoil was stripped, exposing the calcareous duricrust that has essentially stabilised the local land surface.

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TRANSACTIONS OF THE
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DASYUROTAENIA ROBUSTA BEDDARD, 1912, AND D. DASYURI SP. NOV., FROM CARNIVOROUS AUSTRALIAN MARSUPIALS

BY IAN BEVERIDGE

Summary

Dasyurotaenia robusta Beddard, 1912, is redescribed from specimens collected from the type host, the Tasmanian devil, *Sarcophilus harrisi* (Boitard). The rostellar hooks are described for the first time. *Dasyurotaenia dasyuri* sp. nov., from the tiger cat, *Dasyurus maculatus* (Kerr), in Queensland and Tasmania differs from *D. robusta* in the size and shape of the rostellar hooks, the presence of transverse osmoregulatory canals and the number of uterine branches. Specimens from *Dasyurus maculatus*, described in earlier works as *D. robusta* can now be assigned to either species with certainty. Lesions associated with *D. dasyuri* sp. nov. are described and the taxonomic position of the genus discussed.

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Summary

BEVERIDGE, I. (1984) *Dasyurotaenia robusta* Beddard, 1912, and *D. dasyuri* sp. nov., from carnivorous Australian marsupials. *Trans. R. Soc. S. Aust.* **108**(4), 185-195, 13 December, 1984.

Dasyurotaenia robusta Beddard, 1912, is redescribed from specimens collected from the type host, the Tasmanian devil, *Sarcophilus harrisii* (Boitard). The rostellar hooks are described for the first time. *Dasyurotaenia dasyuri* sp. nov., from the tiger cat, *Dasyurus maculatus* (Kerr), in Queensland and Tasmania differs from *D. robusta* in the size and shape of the rostellar hooks, the presence of transverse osmoregulatory canals and the number of uterine branches. Specimens from *Dasyurus maculatus*, described in earlier works as *D. robusta* cannot now be assigned to either species with certainty. Lesions associated with *D. dasyuri* sp. nov. are described and the taxonomic position of the genus discussed.

KEY WORDS: Cestoda, Taeniidae, marsupials, *Dasyurotaenia*.

Introduction

Dasyurotaenia robusta was first described by Beddard (1912) from specimens found in a Tasmanian devil, *Sarcophilus harrisii* (Boitard) (*Dasyurus ursinus*) which died in London at the Gardens of the Zoological Society. Beddard (1912) described a number of unusual morphological features including suckers armed with hooks, and placed the species, with some reservations, in the Taenioidea. Baer (1925) re-examined Beddard's types and indicated that a number of misinterpretations of the morphology of the cestode had been made, including the "armed suckers" which proved to be an armed rostellum. Baer (1925) concluded that the species belonged to an independent genus within the Taenioidea, while Wardle & McLeod (1952), with considerable reservation, placed the genus within the family Taeniidae.

Subsequently, Sandars (1957) redescribed the species based on cestodes collected from two *Dasyurus maculatus* (Kerr) from Tasmania, confirming most of Baer's (1925) observations and concluding that the genus did belong within the Taeniidae. This taxonomic position was accepted by Yamaguti (1959), but it has been questioned by Rausch (1981) on phylogenetic grounds.

Recent collections of cestodes from dasyurids indicate that two independent species of *Dasyurotaenia* have been formerly confused under a single specific name, largely because the rostellar hooks of the species have never described (Beddard 1912, 1915; Baer 1925; Sandars 1957). In addition, a re-examination of the morphology of the two species supports Rausch's contention (1981) that this genus

may not belong to the Taeniidae. In this paper, *Dasyurotaenia robusta* is redescribed from *Sarcophilus harrisii*, the type host, and a new species is described from *Dasyurus maculatus*.

Materials and Methods

Cestodes were relaxed in water, fixed in 10% neutral buffered formal saline, and stored in 70% ethanol. Whole mounts were stained with Celestine blue, dehydrated in graded ethanols, cleared in clove oil and mounted in balsam. Scoleces were mounted in Berlese's fluid, and digital pressure was applied to the cover slip to enable examination of the rostellar hooks. Serial sections cut at a thickness of 5 μ m, were stained with haematoxylin and eosin. Gravid proglottides of *D. dasyuri* which had been fixed in formalin were diced into small cubes, post-fixed in osmium tetroxide and embedded in araldite. Thin sections were stained with lead citrate and uranyl acetate and viewed with a Joel 100 CX electron microscope. Additional specimens of *Dasyurotaenia* were obtained from preserved carcasses of *Dasyurus maculatus* held in the National Museum of Victoria, Melbourne.

Measurements are given in the text, in mm, as the range followed, in parentheses, by the mean and the number of measurements made.

Abbreviations of institutions cited in text: AHC—Australian Helminth Collection, housed in the South Australian Museum, Adelaide; BMNH—British Museum (Natural History), London; MHNG—Muséum d'Histoire Naturelle, Geneva; SAM—South Australian Museum, Adelaide; WAM—Western Australian Museum, Perth; WI—Commonwealth Scientific and Industrial Research Organisation, Division of Wildlife and Rangelands Research, Canberra.

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Dasyurotaenia robusta Beddard, 1912

FIGS 1-11, 26-28

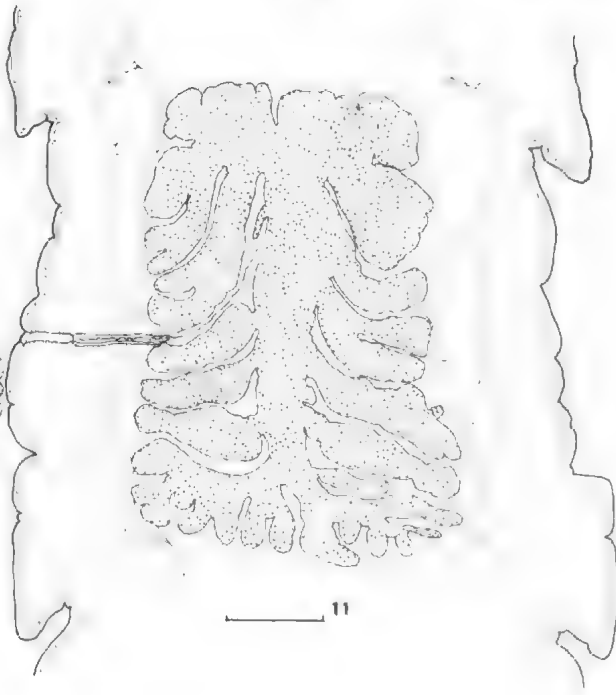
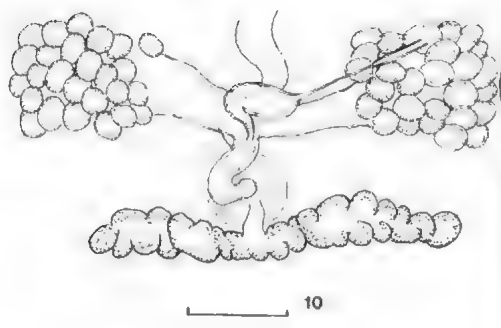
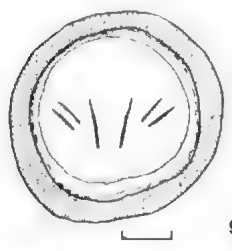
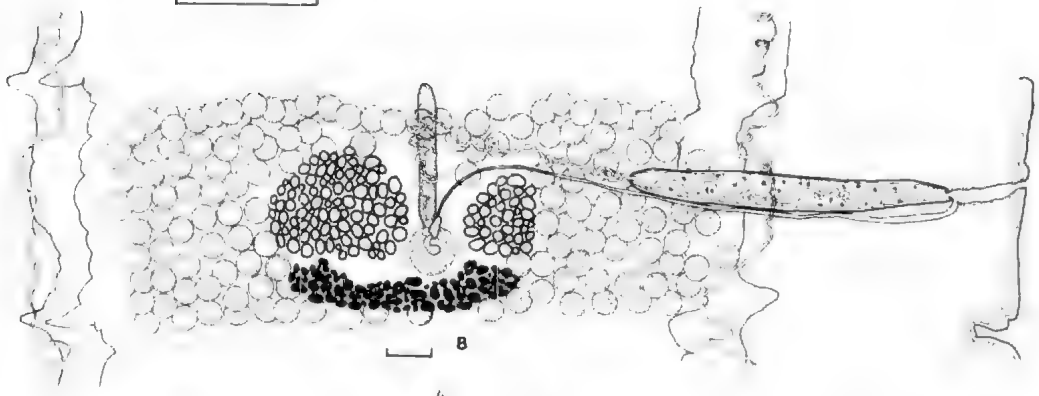
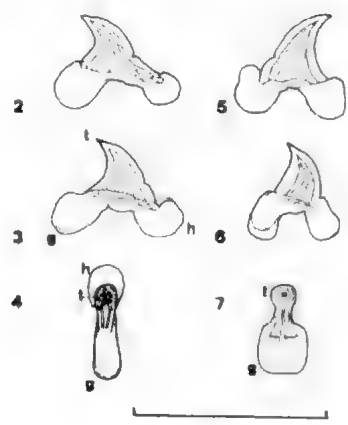
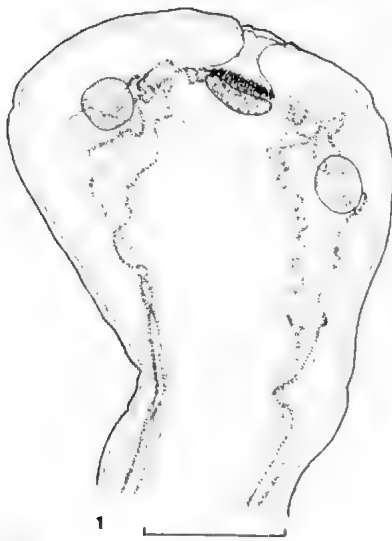
Description: Cestodes of moderate size, up to 140 in length, 4 wide with up to 290 proglottides in gravid strobila. Scolex large (Fig. 1), 2.36 (n=1) in diameter, deeply embedded in intestinal mucosa of host. Suckers 0.30-0.38 (0.33, n=3) in diameter; rostellum 0.44×0.15 (n=1) retracted within scolex, extremely muscular, sucker shaped, with 42 (n=1) rostellar hooks arranged in 2 rows. Large or anterior rostellar hooks (Figs 2-4, 26) 0.046-0.058 (0.054, n=10) long, base 0.056-0.062 (0.059, n=10) long; blade large, core striated, sometimes vacuolated; handle extremely short, relatively wide; guard long, wide, single lobe (Figs 4, 27). Small or posterior rostellar hooks (Figs 5-7) 0.042-0.052 (0.047, n=10) long, base 0.044-0.060 (0.054, n=10) long; blade large, core striated; handle extremely short, knob-like; guard large, flattened, almost bilobed distally (Figs 7, 28). Neck present.

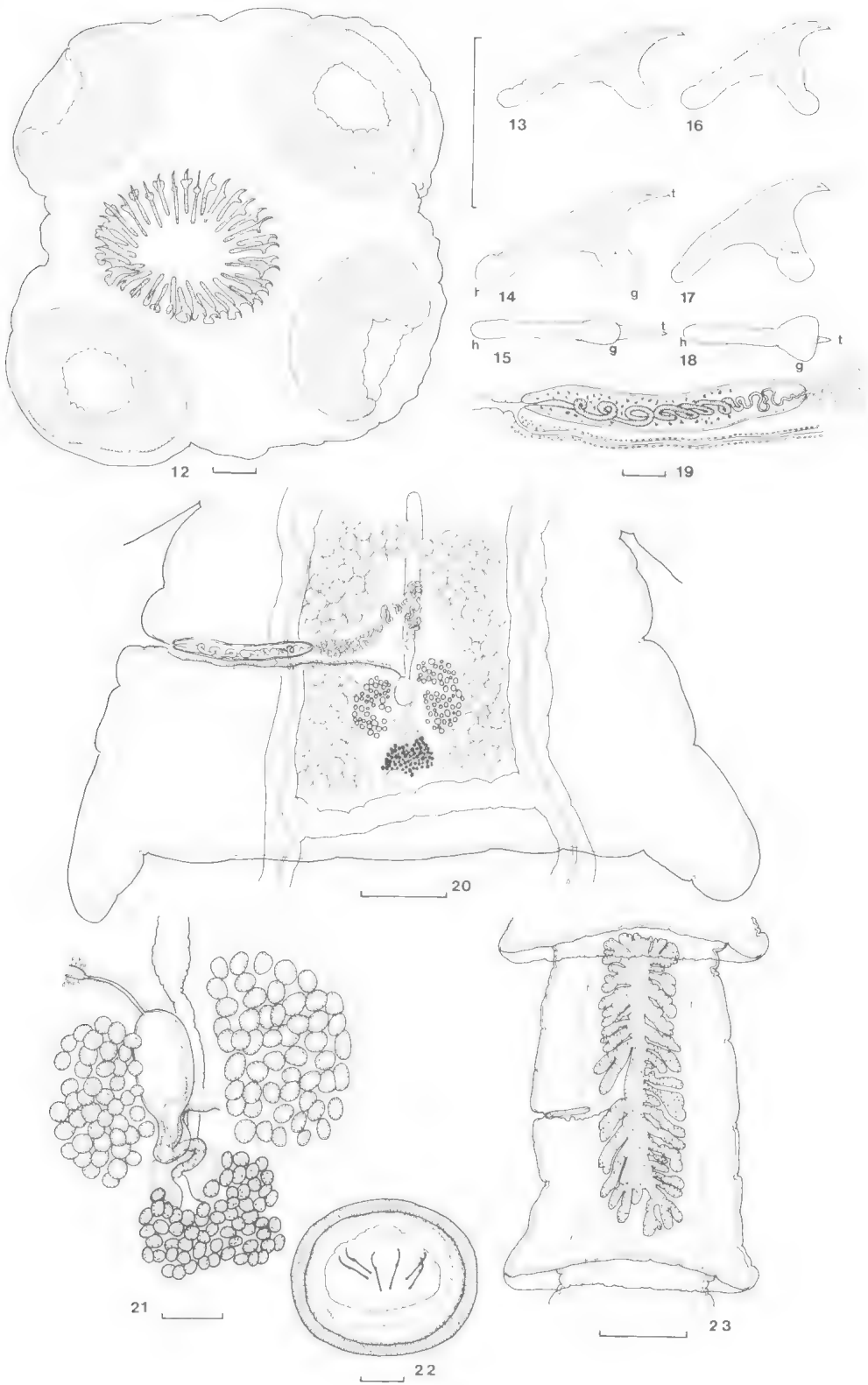
Musculature of mature proglottides poorly developed. Outer longitudinal muscles single or in very small bundles; inner longitudinal muscles in larger bundles containing 20 or more fibres. Transverse muscles in several bands; including bands internal to inner longitudinal muscles and separating inner and outer longitudinal muscles; more poorly defined bands between bundles of inner longitudinal muscles. Dorso-ventral muscles sparse, crossing cortex and medulla at irregular intervals. Longitudinal osmoregulatory canals paired; ventral canal 0.10-0.19 (0.13, n=5) wide in mature proglottides, not joined by transverse canals, with valve-like flaps protruding into lumen at junction of proglottides; in one strobila, ventral canals of gravid proglottides with several smaller projections of canal wall in addition to major valves. Dorsal canal extremely narrow, sinuous, 0.05 (n=1) in diameter in mature proglottides, dorsal or external to ventral canal. Mature proglottides 0.35-0.60 (0.48, n=5) \times 2.45-3.05 (2.77, n=5), length:width ratio 4.8-7.1 (6.0, n=5) (Fig. 8). Gravid proglottides 1.45-2.20 (1.75, n=5) \times 2.60-3.50 (3.18, n=5), length:width ratio 1.2-2.3 (1.9, n=5). Genital pores almost exclusively unilateral, occasional genital pore on alternate side. Genital atrium narrow, situated in middle of lateral proglottis margin in mature proglottides dividing margin in ratio of 1:0.67-1:1.00 (1:0.88, n=5); in middle or posterior half of margin of gravid proglottides, dividing margin in ratio of 1:1.00-1:1.66 (1:1.35, n=5). Genital ducts pass between longitudinal osmoregulatory canals. Cirrus

sac elongate, thin-walled, invariably extending beyond osmoregulatory canals into medulla, 0.60-0.85 (0.74, n=10) \times 0.06-0.09 (0.07, n=10) in mature proglottides. Cirrus slender, approximately 0.01 in diameter, coiled, armature of extremely fine bristles visible on mid-region of cirri in section. Internal and external seminal vesicles absent. Vas deferens greatly coiled, narrow duct, loops medially, then at midline turns posteriorly, terminating between lobes of ovary. Vasa efferentia not seen. Testes numerous, situated in 1-2 layers in dorsal plane. Testes occupy most of medulla between osmoregulatory canals, occasionally extend over osmoregulatory canals on poral side of proglottis with small numbers of testes being outside canals (Fig. 8); testes confluent anterior to ovaries and frequently confluent posterior to vitellarium in 1 or 2 rows; row of testes posterior to vitellarium sometimes interrupted; always some testes posterior to vitellarium; small numbers of testes overlie ovaries. Testes number 170-223 (200, n=10) per proglottis; diameter 0.05-0.10 (0.08, n=10). Vagina 0.010-0.020 (0.015, n=5) in diameter, straight, lined internally by hairs or bristles, surrounded by single layer of glandular cells. Proximal of 0.16 of vagina of wider internal diameter, unarmed. Seminal receptacle small, 0.06-0.08 (0.07, n=5) \times 0.02-0.04 (0.03, n=5), situated in mid-line between lobes of ovary (Fig. 10). Ovary bilobed, poral lobe smaller, 0.14-0.32 (0.21, n=10) \times 0.21-0.40 (0.29, n=10), aporal lobe 0.16-0.30 (0.23, n=10) \times 0.27-0.48 (0.38, n=10), joined by narrow isthmus. Vitellarium posterior to ovary, elongate laterally 0.07-0.14 (0.11, n=10) \times 0.47-0.90 (0.70, n=10). Mehlis' gland spherical, 0.08-0.10 (0.09, n=5), in diameter, between vitellarium and seminal receptacle. Uterus arises as tubular structure in midline. Uterus in gravid proglottides with 6-9 (7, n=10) poral and 7-10 (9, n=10) aporal lateral uterine branches; uterine branches frequently subdivided laterally (Fig. 11). Eggs approximately spheroidal 0.033-0.048 (0.042, n=10) \times 0.035-0.040 (0.038, n=10) (Fig. 9); embryophore thick, homogenous, non-striated, oncosphere 0.028-0.033 (0.030, n=10) \times 0.023-0.030 (0.027, n=10); oncospherical hooks 0.008-0.010 (0.009, n=10).

Development of genital organs in single specimen 140 long: testes first visible in proglottis 95; first mature proglottis approx. 160; uterine filling commences in proglottis 190; male and female genitalia involution by proglottis 230; fully branched uterus

Figs 1-11. *Dasyurotaenia robusta* Beddard. 1. Scolex with rostellum retracted; 2-7, rostellar hooks; 2, 3, large or anterior rostellar hooks, lateral view; 4, large rostellar hook, radial view; 5, 6, small or posterior rostellar hooks, lateral view; 7, small rostellar hook, radial view; 8, mature proglottis; 9, egg; 10, female genitalia; 11, gravid proglottis. Scale lines: fig. 1, 1.0 mm; figs 2-8, 11, 10, 0.1 mm; fig. 9, 0.1 mm. g—guard; h—handle; t—tip.





present by proglottis 250; first gravid proglottis 278; total number proglottides 290.

Host: *Sarcophilus harrisii* (Boitard, 1841) (Marsupialia: Dasyuridae).

Site in host: Small intestine.

Types: Collected: London Zoological Society Gardens; slides of serial sections MHNG 24/53-61.

Material examined: types; 3 specimens, Adelaide Zoological Gardens, 7.vi.1980, collected by M. G. O'Callaghan, AHC 8291 and 81384; 1 specimen (without sex), Chicago Zoological Gardens, collected by V. Rondani, BMNH.1967.9.28.23.

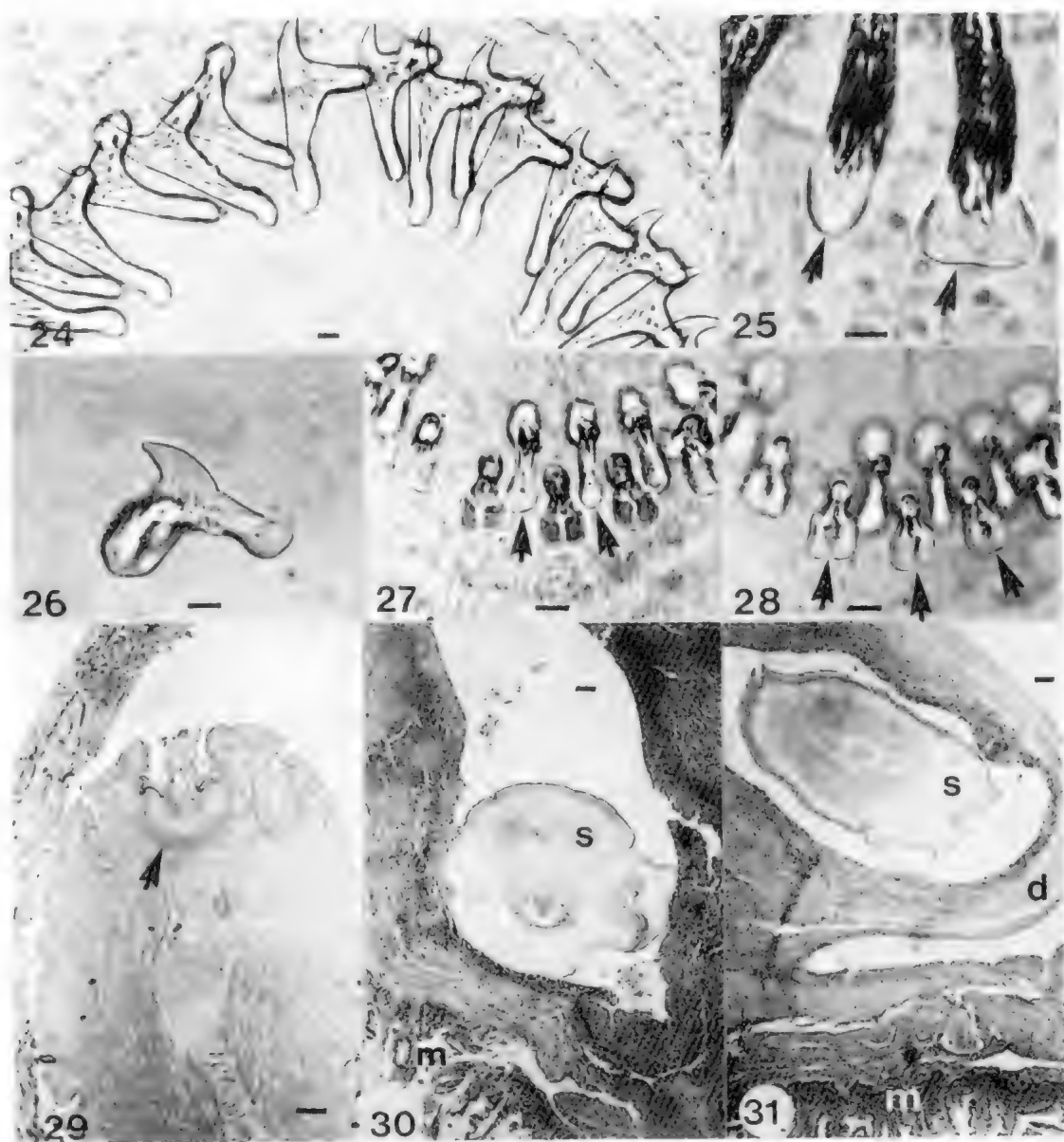
Dasyurotaenia dasyuri sp. nov.

FIGS 12-23, 24, 25, 29-31

Description (from types): Large cestodes, 237-506 (400, $n=5$) in length, 2.5-3.9 (2.8, $n=5$) wide, with 280-330 (310) proglottides in gravid strobilae. Scolex large, 2.40 ($n=1$) in diameter, deeply embedded in mucosa of host. Suckers 0.32-0.38 (0.35, $n=9$) in diameter, rostellum 0.38-0.50 (0.43, $n=4$) in diameter with 36-38 ($n=4$) rostellar hooks arranged in two rows (Fig. 12). Large or anterior rostellar hooks 0.105-0.110 (0.107, $n=20$) long, base 0.077-0.093 (0.085, $n=20$) long (Figs 13, 14, 24); blade large, core frequently vacuolated; handle extremely small; guard elongate, not enlarged towards extremity (Figs 15, 25). Small or posterior rostellar hooks 0.080-0.093 (0.087, $n=20$) long, base 0.060-0.083 (0.075, $n=20$) long (Figs 17, 24); blade large, core frequently vacuolated; handle virtually absent, guard large, broad, frequently bilobed distally (Figs 18, 25). Neck present. Musculature not strongly developed. Outer longitudinal muscles single or in small bundles of 2-5 fibres, inner longitudinal muscles in larger bundles, up to 0.025 in diameter, containing 20 or more fibres. Transverse muscles in several bands; two most prominent bands immediately internal to inner longitudinal muscles and separating inner and outer longitudinal muscles; poorly defined bands between bundles of inner longitudinal muscles. Dorsal-ventral muscles sparse, single, crossing cortex and medulla at irregular intervals. Longitudinal osmoregulatory canals paired; ventral canals 0.11-0.17 (0.15, $n=5$) in diameter in mature proglottides, joined at posterior margin of each proglottis by broad transverse canal. Ventral canals with valve like flaps protruding into lumen at junction of proglottides. Dorsal canal extremely narrow, sinuous, 0.01 ($n=5$) in diameter in mature proglottides. Mature proglot-

tides 1.4-2.5 (1.7, $n=10$) \times 2.5-3.0 (2.9, $n=10$), length:width ratio 1.02-2.64 (1.84, $n=10$) (Fig. 20). Gravid proglottides 1.8-3.9 (2.7, $n=10$) \times 1.9-3.3 (2.8, $n=10$), length:width ratio 0.71-1.53 (1.07, $n=10$). Genital pores mainly unilateral, occasionally alternate irregularly. Genital atrium shallow, situated in anterior half of lateral proglottis margin in mature proglottides, dividing margin in ratio 1:1.3-1:2.4 (1:1.8, $n=10$); in middle of margin in gravid proglottides, dividing margin in ratio 1:0.9-1:1.5 (1:1.1, $n=10$). Genital ducts pass between longitudinal osmoregulatory canals. Cirrus sac elongate, thin-walled (Fig. 19) invariably extending beyond osmoregulatory canals into medulla, 0.50-0.71 (0.57, $n=10$) \times 0.08-0.12 (0.10, $n=10$) in mature proglottides. Cirrus slender, 0.01-0.02 (0.015, $n=5$) in diameter, coiled, armature of fine hairs visible on distal region of some cirri under high magnification. Internal and external seminal vesicles absent. Vas deferens greatly coiled, narrow duct, loops medially and anteriorly, then at mid-line turns posteriorly, terminating near seminal receptacle. Vasa efferentia not seen. Testes numerous, situated in 1-2 layers in dorsal planes. Testes occupy most of medulla between osmoregulatory canals, except area of female genitalia; testes confluent anterior to vas deferens; testes usually confluent posterior to vitellarium, or with 1-3 testes posterior to and overlying vitellarium; occasionally no testes posterior to vitellarium. Testes number 150-160 ($n=2$) per proglottis; diameter 0.06-0.08 (0.07, $n=10$). Vagina approximately 0.12 in diameter, straight, lined internally by fine hairs, surrounded externally by single layer of glandular cells. Proximal 0.15 of vagina narrow, surrounded by thicker muscle layer than remainder of vagina, lacking glandular cell investment. Seminal receptacle ovoid (Fig. 21), 0.11-0.16 (0.14, $n=10$) \times 0.07-0.10 (0.9, $n=10$) when filled, situated in mid-line between lobes of ovary. Ovary bilobed, polar lobe small, 0.26-0.39 (0.31, $n=10$) \times 0.12-0.25 (0.20, $n=10$), apical lobe 0.32-0.44 (0.37, $n=10$) \times 0.15-0.30 (0.21, $n=10$), joined by narrow isthmus. Vitellarium posterior to ovary, reniform 0.12-0.24 (0.20, $n=10$) \times 0.18-0.31 (0.23, $n=10$). Mehlis' gland spherical, 0.07-0.11 (0.09, $n=10$) in diameter, between vitellarium and seminal receptacle. Uterus arises as tubular structure in midline. Uterus in gravid proglottides (Fig. 23) with 6-17 (12, $n=10$) polar and 10-20 (15, $n=10$) apical lateral uterine branches; uterine branches frequently subdivided laterally. Egg approximately spheroidal

Figs 12-23. *Dasyurotaenia dasyuri*, sp. nov. 12. Scolex, apical view; 13-18, rostellar hooks, 13, 14, large or anterior rostellar hooks, lateral view; 15, large rostellar hook, apical view; 16, 17, small or posterior rostellar hooks, lateral view; 18, small rostellar hook, apical view; 19, cirrus sac and distal vagina; 20, mature proglottis; 21, female genitalia; 22, eggs; 23, gravid proglottis. Scale lines: Figs 12, 13-19, 21, 0.1 mm; fig. 20, 0.35 mm; fig. 22, 0.01 mm; fig. 23, 1.0 mm. g—guard; h—handle; i—tip.



Figs 24-25. Rostellar hooks of *Dasyurotaenia dasyuri*, sp.nov.; 24, apical view of rostellum, hooks in lateral view; 25, apical view of hooks showing differences in shape of guards of large and small hooks (arrowed). Scale lines 0.01 mm.

Figs 26-28. Rostellar hooks of *Dasyurotaenia robusta* Beddard; 26, large rostellar hooks, lateral view; 27, 28, apical view of hooks showing difference in shape of guard of large and small hooks (arrowed). Scale line 0.01 mm.

Figs 29-31. Histological features of scolex of *Dasyurotaenia dasyuri* sp.nov. and associated pathology; 29, sagittal section through scolex showing partly withdrawn rostellum; 30 scolex(s) lodged in muscularis externa immediately below mucosa (m); 31, scolex(s) lodged in muscularis close to serosal margin showing dome shaped projections of tissues (d) beyond normal serosal surface intestine and mucosa (m). Scale lines 1 mm.

(Fig. 22), 0.035–0.040 (0.038, $n=10$) \times 0.030–0.034 (0.032, $n=10$); embryophore thick, homogenous, non-striated, oncosphere 0.022–0.025 (0.024, $n=10$) \times 0.016–0.018 (0.017, $n=10$); oncospherical hooks 0.008–0.010 (0.008, $n=10$). Development of genital organs in 5 specimens: anlage first visible in proglottides 60–120 (85); testes first visible in proglottides 180–190 (187); first mature proglottis approximately 205–220 (215); uterine filling commences in proglottides 225–265 (245); first gravid proglottis 270–320 (305); total proglottides 280–330 (310).

Variation: Specimens from Tas.; identical to types, except in the following minor features: rostellar hook number more variable than in types, 32–40 (37, $n=3$); large rostellar hooks 0.110–0.120 (0.116, $n=10$), and small rostellar hooks 0.093–0.098 (0.095, $n=10$) both slightly larger (approximately 0.010) than hooks of type specimens; testes number 169–226 (186, $n=10$) per proglottis, higher than in types; vitellarium 0.10–0.15 (0.13, $n=10$) \times 0.21–0.38 (0.30, $n=10$) relatively wider and shorter than in types.

Host: *Dasyurus maculatus* (Kerr, 1792) (Marsupialia: Dasyuridae).

Site in host: Small intestine.

Types: Holotype, 8 paratypes, Mt Windsor Tableland, Qld, 16°12'S, 145°05'E, 17.vii.1982, coll. D. M. Spratt. Holotype, 2 slides SAM V3459, 3 paratypes, SAM V3460–V3462; 4 paratypes, AHC S2169–S2172, HC 12322; 1 paratype, BMNH 1983.6.13.1–2; 1 scolex, strobilar fragments, paratypes, in collection of R. L. Rausch.

Fine structure of the egg envelopes (Fig. 32): The following envelopes were recognised surrounding the oncosphere. The outer envelope of the egg is bounded by a thin vitelline membrane, enclosing an irregular cytoplasmic layer. The outer

embryophoric membrane lies immediately external to the thickened embryophore. The embryophore is of uniform thickness and is composed of relatively homogenous electron dense material which is not organised into regular embryophoric blocks and is without lacunae or internal circular bodies. Some areas within the embryophore are less electron dense and suggest cavities between blocks but are not arranged in a regular fashion. A zone of electron dense granules, the granular layer, lies between the embryophore and a broad sub-embryophoric vacuolated area which may represent aggregations of lipid bodies. The vacuolated zone and granular layer is bounded internally by the inner embryophoric membrane. Internal to this lies the oncosphere bounded by the oncospherical membrane.

Material examined: Qld: types: Tas.: 3 specimens, Smithton, coll. B. L. Munday, 1.vii.1979; 3 specimens, Smithton, coll. D. M. Spratt, 26.iii.1968, WI. C282, C43; 2 specimens, 1 Sydney, coll. B. L. Munday, 2.vii.1976, AHC, HC10732; fragments of specimens, Wynard, coll. unknown, 22.vi.1922, whole preserved carcass NMV C6304, cestodes AHC 9785.

Associated Lesions (Figs 29–31): Scoleces of *D. dasyuri* lie deeply embedded in the external muscle layers of the wall of the small intestine of the host, either superficially, that is immediately below the submucosa, or, close to the serosal margin of the musculature such that the position of the cestode scolex is indicated by a raised dome-shaped projection on the serosal surface. The neck and anterior region of the strobila lie in a narrow tunnel which opens into the intestinal lumen. Two specimens of *D. dasyuri* were embedded singly, two were embedded together, and a further three worms were embedded at a single site. The superficial layers lining the cavities induced by cestode invasion consist primarily of necrotic cells and of cell debris together with viable cells compressed by the distention of surrounding tissues. There are in addition, surrounding the scoleces, a few small localised areas of necrosis of the myocytes and infiltrations by inflammatory cells. The principal host reaction is a chronic inflammatory one with an infiltration of macrophages and lymphocytes and a few plasma cells into tissues surrounding the cestode. Polynuclear leukocytes are uncommon, but Langhans-type giant cells are occasionally present at the edges of lesions. Fibroblasts are prominent in a few areas on the outer edges of infiltrated areas.

Discussion

In none of the previous descriptions of *Dasyurotaenia* by Beddard (1912, 1915), Baer (1925) or Sanders (1957) have the rostellar hooks been adequately described. Beddard (1912) provided drawings of the

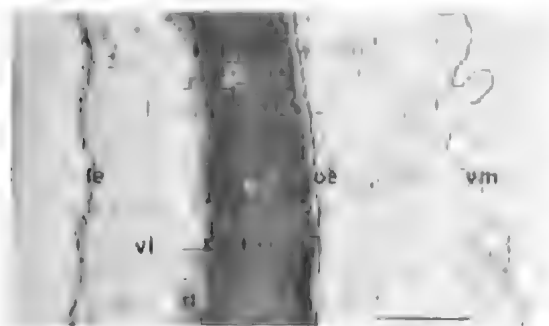


Fig. 32. Transmission electron micrograph of egg envelopes, *Dasyurotaenia dasyuri*. Scale line, 30 μ m. e—embryophore; g—granular layer; ie—inner embryophoric membrane; oe—outer embryophoric membrane; vl—vacuolated layer; vi—vitelline membrane.

histology of a purported sucker of *D. robusta* showing sections of sclerotized hooks but did not describe the size or shape of the hooks. Baer (1925) had no scoleces to examine, but concluded from Beddard's description that the cestode in question possessed a rostellum armed with taeniid-like hooks. Sandar's specimens (1957), here attributed to another species, were without rostellar hooks, but were re-described under the name *D. robusta*. She estimated that some 96 hooks were normally present.

The material described above indicates that in the past two (or more) independent species have been confused under the single name *D. robusta*. The two species described in this paper differ markedly in the size and shape of the rostellar hooks, but have few differences of note in strobilar morphology, and this has undoubtedly led to the confusion.

D. robusta is known only from the type series collected from Tasmanian devils in the London Zoological Gardens, from the three specimens described here, collected from the same host species in the Adelaide Zoological Gardens and from a single specimen without scolex from the Chicago Zoo. Beddard (1915) reported the species in four of nine devils dying in the Gardens; however, examination of 294 devils in Tasmania has not revealed its existence (Gregory *et al.* 1974).

The present redescription, although based upon a very limited series of specimens is considered justified as the species may now be rare, and since the material available allows a fairly full description to be made for the first time, including the distinguishing features of the rostellar hooks.

D. robusta is distinguished from *D. dasyuri* by the form and size of the rostellar hooks (Figs 2-7, 13-18). The large rostellar hooks of *D. robusta* are only 0.046-0.058 long compared with 0.105-0.120 in *D. dasyuri*. In addition, the size of the hook blade is relatively smaller in *D. robusta* so that the length of the hook base is larger, on average, than the total length of the hook; in *D. dasyuri* the length of the base is less than the total hook length. In both species, the guard of the small hook is particularly broad, and this is more marked in *D. robusta* than in *D. dasyuri*.

The principal strobilar character distinguishing *D. robusta* from *D. dasyuri* is the transverse osmoregulatory canal joining the ventral canals on both sides of the strobila in each proglottis. The difference is not immediately obvious in mature proglottides, but the canals are readily visible in most gravid and near gravid proglottides and the presence or absence of transverse osmoregulatory canals can be readily ascertained. Beddard (1912) noted the lack of transverse canals in the type specimens of

D. robusta, and Baer (1925) confirmed that the canals were not visible in Beddard's sections, but suggested that their absence might be more apparent than real owing to the severely contracted nature of the type specimens. The new material confirms Beddard's (1912) observations that transverse canals do not exist.

Beddard (1912) discussed at some length the "membranes" stretching across the lumen of the osmoregulatory canals, noting that the lumen was occluded by "membranes" once in each proglottis. Baer (1925) explained Beddard's observations in terms of oblique histological sections passing through consecutive coils of the osmoregulatory canal, suggesting that the "membranes" were essentially artefacts due to the state of contraction of the specimens. The new specimens indicate that Beddard's observations were correct. At the posterior end of the proglottis in *D. robusta* and *D. dasyuri*, the lumen of the osmoregulatory canal is largely occluded by a valve-like extension of the canal wall. The structure is in most respects identical to valves which occur in comparable positions in the osmoregulatory canals of species of *Taenia*, described in detail by Kohler (1894). In specimens of *D. robusta*, the ventral canals are of extremely variable diameter, and in some incompletely relaxed proglottides, there are occasional folds in the canal wall similar to the incomplete "membranes" described by Beddard (1912). Baer (1925) was probably correct in ascribing these changes to the state of relaxation of the specimens.

The two species also differ in the number of lateral uterine branches, with 6-10 (9) in *D. robusta* and 6-20 (14) in *D. dasyuri*. Although these differences appear to be consistent in the material examined, they should be treated with some caution since Verster (1967) in a rescription of *Taenia solium* Linnaeus, 1758 and *T. saginata* Goze, 1782, two species which have frequently been identified from gravid proglottides by difference in the number of uterine branches, found that overlap in uterine branch number occurred if a sufficient number of proglottides was examined. Some overlap obviously occurs in uterine branch numbers of *Dasyurotaenia* spp. and more extensive series of specimens are required to test the validity of uterine branch number as a taxonomic character in this genus.

A number of minor morphological differences noted between *D. robusta* and *D. dasyuri* require more detailed examination in larger numbers of specimens before their reliability can be established. (i) The vitellarium was much shorter and wider in *D. robusta* (Figs 10, 20); however, this may have been due to the incomplete state of relaxation of the specimens of *D. robusta*. In addition, there was variation in the dimensions of the vitellarium be-

tween specimens of *D. dasyuri* from Tas. and Qld the latter specimens (the types) having much narrower vitellaria. (ii) In specimens of *D. robusta*, testes were occasionally found overlying the osmoregulatory canals or even entirely lateral to them, in contrast to *D. dasyuri* in which the testes invariably lie between the canals. (iii) The seminal receptacle in *D. robusta* was smaller than *D. dasyuri*, and the cirrus sac slightly longer and more prominent. All features mentioned require examination in an extensive series of specimens before any confidence can be placed upon their ability to distinguish the two species.

The data presented above suggest that *D. robusta* is confined to *Sarcophilus harrisii* and that *D. dasyuri* occurs only in *Dasyurus maculatus*. Sandars's (1957) specimens described under the name *D. robusta* but collected from *Dasyurus maculatus* in Tas. cannot definitely be assigned to either species, since they had no testicular hooks. She stated that no transverse osmoregulatory canals could be seen, but prefaced her remarks by saying that details of the osmoregulatory canals could not be determined. It would therefore be unwise to assume that her specimens were *D. robusta* based on her failure to find transverse osmoregulatory canals. Her figure (Fig. 27) of a gravid proglottis reveals 12-14 lateral uterine branches, suggesting that the specimens she described may have been in fact *D. dasyuri* and not *D. robusta*. However, *Dasyurotaenia* is probably represented by several species in dasyurid marsupials. In addition to the new species described here, a single juvenile cestode with 96 testicular hooks, probably representing yet another species, was co-parasitic with the type specimens of *D. dasyuri* and has been deposited in AHC (S2173). Sandars's (1957) specimens could be attributed to this species or could have been a mixture of two species, *D. dasyuri* and the undescribed species. Another probably new species with 18-22 hooks, 0.100-0.108 and 0.092-0.104 long from *Dasyurus albopunctatus* Schlegel, 1880, in New Guinea is represented by two specimens only in the collection of the BMNH (1973.7.9.5-6). More specimens are required before the species can be described adequately. Finally, juvenile cestodes with 54 hooks 0.152-0.156 and 0.122-0.126 long were present in a specimen of *Satanellus hallucatus* Gould, 1842 from W.A. The specimens probably represent a new species of *Dasyurotaenia* and have been deposited in WAM (79.80.81-1983).

A metacestode of *Dasyurotaenia*, identified as *D. robusta* was reported from the peritoneal cavity of *Potomus tridactylus* (Kern, 1792) in Tas. by Gregory (pers. comm. in Beveridge, 1978). This particular specimen had been identified by comparison with

scoleces from *Dasyurus maculatus*, and is now considered to be a metacestode of *D. dasyuri*.

The occurrence of the scolex deeply embedded within the intestinal wall of the host is unusual among cestodes. *Paradilepis scolecina* (Rudolphi, 1819) burrows into the small intestine of coromoran *Phalacrocorax carbo* Linnaeus, the scolex lodging in the muscularis externa close to the serosa (Karstad *et al.* 1982), and a singular localisation has been reported for *Paradilepis deluchauxi* (Luhmann, 1909) in *Phalacrocorax africanus* (Gmelin) by Baer (1959). In mammals, the anoplocephalid *Ectoparaphidium abei* Rausch & Ohbayashi, 1974, occurs with its scolex deeply buried in the wall of the sacculus rotundus of the pikas *Ochotona myles* (Ogilby) and *O. macrotis* (Günther) (Rausch & Ohbayashi, 1974). The mechanisms of invasion of *Dasyurotaenia* were not clear from the material studied. *Dasyurotaenia* spp. do not have prominent testicular glands to secrete proteolytic enzymes such as are present in *E. abei*, but material from *D. maculatus* (WLC43) does suggest that the juvenile cestodes of *D. dasyuri* become deeply embedded in the small intestine wall before the initiation of proglottisation. The histological reaction to the scolex of *D. dasyuri* is similar to that described for *P. scolecina* and *E. abei*.

The genus *Dasyurotaenia* was allocated to the Taeniidae by Baer (1925) and this was confirmed subsequently by Sandars (1957). Rausch (1981) however has emphasised that the family, in the form recognised by Abuladse (1965) and Yamaguti (1959) is obviously polyphyletic. *Cladotaenia* Cohn, 1901 as indicated by Freeman (1973), belongs in the Dilepididae, based on the morphogenesis of the metacestodes, though the morphology of mature and gravid proglottides is similar to the taeniids. *Anoploetaenia* Beddard, 1911, a parasite of the Tasmanian Devil, likewise has a proglottis morphology akin to the Taeniidae while metacestode development indicates affinities with the Linstowiidae (Beveridge 1982). In ascertaining the true relationship of genera within the Taeniidae, it is obvious that a knowledge of metacestode development is a pre-requisite, and these data currently are lacking for *Dasyurotaenia*. As a consequence, morphological data cannot be the basis for a final determination of its taxonomic position, but may provide clues.

Dasyurotaenia is distinguished from other genera of the Taeniidae (*sensu* Yamaguti 1959) by the large scolex embedded deeply in the tissues of the host and by the essentially unilateral genital pores. Sandars (1957) mentioned the general body shape, the structure of the scolex, the form of the cirrus sac and the development of the musculature as features distinguishing the genus. While the form of the cir-

rus sac is markedly different from *A. dasyuri*, a coparasite of the Tasmanian devil, it does not differ from most *Taenia* spp. and therefore cannot be considered diagnostic. Of the characters mentioned by Sandars (1958), only the arrangement of the musculature seems worthy of consideration as it is apparently unique in the family. Unfortunately, the musculature of many species of the Taeniidae has not been described in detail, and its value as a taxonomic character for *Dasyurotaenia* is therefore open to some doubt at present.

The structure of the egg likewise is inconclusive. The embryophore is extremely thick, as in taeniids, but is not composed of radially arranged blocks with lacunae (see Fairweather & Threadgold 1981) nor is it characteristic of dilepidid eggs (Pence 1967). In *A. dasyuri*, the structure of the egg was interpreted as being typically taeniid (Beveridge *et al.* 1975) yet the morphogenesis of the metacestode of this species indicates linstowiid affinities. Hence, there is some doubt as to the taxonomic significance of egg structure, and little weight can be placed upon the presence of a thick embryophore and insignificant outer envelope in the egg of *D. dasyuri*.

In *D. robusta*, the rostellum is apparently retractable, and can be retracted fully within the scolex. This characteristic, shown in Fig. 1, has been overlooked by previous writers, but it is not a characteristic of *Taenia* or *Echinococcus* (see Wardle & McLeod 1952), the only two genera considered by Rausch (1981) as belonging to the Taeniidae. A retractable rostellum is a feature of the Dilepididae and Hymenolepididae (Wardle & McLeod 1952) and

may indicate an affinity with these groups rather than with the Taeniidae.

In summary, none of the morphological data provided allows the definitive allocation of *Dasyurotaenia* to a family. Superficially it resembles the Taeniidae, but the retractable rostellum of the type species, the musculature, and structure of the egg, cast doubt on such affinities.

Rausch (1981) suggested that *Dasyurotaenia* could not be allocated to the Taeniidae on phylogenetic as well as morphological grounds, alluding to the evolution of the Dasyuridae in isolation from eutherian mammals, and the belief that the true taeniids have evolved exclusively within recent Carnivora. If this is the case, *Dasyurotaenia* may exhibit a strobilar morphology convergent with species of *Taenia*, yet be derived from alternative origins, either the Linstowiidae of dasyurid and peramelid marsupials (Beveridge *et al.* 1975, Beveridge 1982) or Diplepididae from accipitriform birds (Beveridge *et al.* 1975). Elucidation of the life cycle of the parasite will be required before a final answer can be given.

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NEW RECORDS OF GLOBOCEPHALOIDINAE (NEMATODA: TRICHOSTRONGYLOIDEA) FROM MACROPODIDAE IN NORTH QUEENSLAND

BY I. BEVERIDGE, R. SPEARE & P. M. JOHNSON

Summary

Globocephaloides affinis Johnston & Mawson, 1939, is resurrected as a valid species and redescribed. The male is described for the first time. *G. affinis* differs from congeners by the possession of a gubernaculum, in the form of the spicules and in the size of the buccal capsule. It occurs in *Macropus dorsalis* and rarely in *M. giganteus*. *G. macropodis* Yorke & Maplestone, 1926, was found in *Macropus agilis*, *M. dorsalis*, *M. parryi*, *Wallabia bicolor*, *Lagorchestes conspicillatus* and *Aepyprmnus rufescens*. *M. parryi*, *W. bicolor*, *L. conspicillatus* and *A. rufescens* are new host records. *Amphicephaloides thylogale* Beveridge, 1979, was found only in *Thylogale stigmatica*, and has not previously been recorded from this host in Queensland.

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Summary

BEVERIDGE, I., SPEARE, R. & JOHNSON, P. M. (1984) New records of Globocephaloidinae (Nematoda: Trichostrongyloidea) from Macropodidae in north Queensland. *Trans. R. Soc. S. Aust.* **108**(4), 197-201, 13 December, 1984.

Globocephaloides affinis Johnston & Mawson, 1939, is resurrected as a valid species and redescribed. The male is described for the first time. *G. affinis* differs from congeners by the possession of a gubernaculum, in the form of the spicules and in the size of the buccal capsule. It occurs in *Macropus dorsalis* and rarely in *M. giganteus*. *G. macropodis* Yorke & Mapleson, 1926, was found in *Macropus agilis*, *M. dorsalis*, *M. parryi*, *Wallabia bicolor*, *Lagorchestes conspicillatus* and *Aepyprymnus rufescens*. *M. parryi*, *W. bicolor*, *L. conspicillatus* and *A. rufescens* are new host records. *Amphicephaloides thylogale* Beveridge, 1979, was found only in *Thylogale stigmatica*, and has not previously been recorded from this host in Queensland.

KEY WORDS. *Globocephaloides*, *Amphicephaloides*, Nematoda, distribution, hosts, morphology, Macropodidae.

Introduction

The trichostrongyloid subfamily Globocephaloidinae Inglis, 1968, consists of three nematode species belonging to the genera *Globocephaloides* Yorke & Mapleson, 1926 and *Amphicephaloides* Beveridge, 1979, occurring in the duodenum of macropodid marsupials and currently placed within the family Herpetostromylinidae (Durette-Desset & Chabaud 1981). In a recent review of the subfamily (Beveridge 1979), two species of *Globocephaloides* were recognised as valid and a new monotypic genus, *Amphicephaloides*, restricted to pademelons (*Thylogale* spp.) was described. The distribution and prevalence of *G. trifidospicularis*, a species occurring in south-eastern Australia, was reported. The lack of extensive parasite collections from northern areas of the continent restricted any considerations of the distribution and abundance of *G. macropodis* which is apparently limited to tropical Australia. Recent collections of nematodes from kangaroos and wallabies in north Queensland have provided additional information on the prevalence and distribution of *G. macropodis* and

Amphicephaloides thylogale as well as indicating that *G. affinis* Johnston & Mawson, 1939, a species described originally from females only and suppressed by Beveridge (1979) as a synonym of *G. macropodis*, is in fact a valid species. In this paper, *G. affinis* is resurrected, the male of *G. affinis* is described for the first time, and additional host and geographic records are given for *G. macropodis* and *A. thylogale*.

Methods

Nematodes were collected from the content of the duodenum of kangaroos and wallabies either immediately following the death of the host or from viscera preserved in 10% formal saline. Duodenal content was washed in a fine sieve and the residue examined using a dissection microscope. Live nematodes were fixed in boiling 70% ethanol and stored in 70% ethanol with 5% glycerine. All specimens are deposited in the Australian Helminthological Collection (AHC) housed in the South Australian Museum, and collection numbers are cited in the text.

Drawings were made with the aid of a camera lucida from specimens cleared in lactophenol. In the descriptions, measurements are given in millimetres as the range followed by the mean of five measurements in parentheses.

Results

The prevalence of *Globocephaloides* and *Amphicephaloides* in macropodids from north Queensland is shown in Table 1.

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TABLE 1. Prevalence of *Globocephaloides* and *Amphicephaloides* in macropodids from northern Queensland.

Macropodid species	No. examined	<i>G. macropodis</i>		<i>G. affinis</i>		<i>A. thylogale</i>	
		Prevalence %	No. worms (mean)	Prevalence %	No. worms (mean)	Prevalence %	No. worms (mean)
<i>Macropus agilis</i> (Gould, 1842)*	40	30	1-10(3)	0	—	0	—
<i>Macropus antilopinus</i> (Gould, 1842)	10	0	—	0	—	0	—
<i>Macropus dorsalis</i> (Gray, 1837)	22	59	2-28(7)	68	1-11(4)	0	—
<i>Macropus giganteus</i> Shaw, 1790	26	0	—	4	1	0	—
<i>Macropus parryi</i> (Bennett, 1835)	15	13	1,32	0	—	0	—
<i>Macropus robustus</i> Gould, 1841	21	0	—	0	—	0	—
<i>Wallabia bicolor</i> (Desmarest, 1804)	9	11	1	0	—	0	—
<i>Aepyprymnus rufescens</i> (Gray, 1837)	11	9	4	0	—	0	—
<i>Thylogale stigmatica</i> Gould, 1860	10	0	—	0	—	40	1-28(9)
<i>Largorcheses conspicillatus</i> Gould, 1842	9	11	9	0	—	0	—
<i>Onychogalea unguifera</i> (Gould, 1841)	10	0	—	0	—	0	—

* Data from Speare *et al.* (1983).

Globocephaloides affinis Johnston & Mawson, 1939
(FIGS 1-18)

Material examined: From *Macropus dorsalis*: Qld: 6 ♂, 2 ♀, Milman, AHC 12741; 1 ♀, Mt Surprise, AHC 12742; 7 ♂, 18 ♀, Warrawee Station via Charters Towers, AHC 12321, 12316, 12737; 1 ♂, 6 ♀, Pallamana Station via Charters Towers, AHC 12738; 8 ♂, 16 ♀, Harvest Home Station via Charters Towers, AHC 12739.

From *Macropus giganteus*: Qld: 1 ♂, Harvest Home Station via Charters Towers, AHC 12740.

Description:

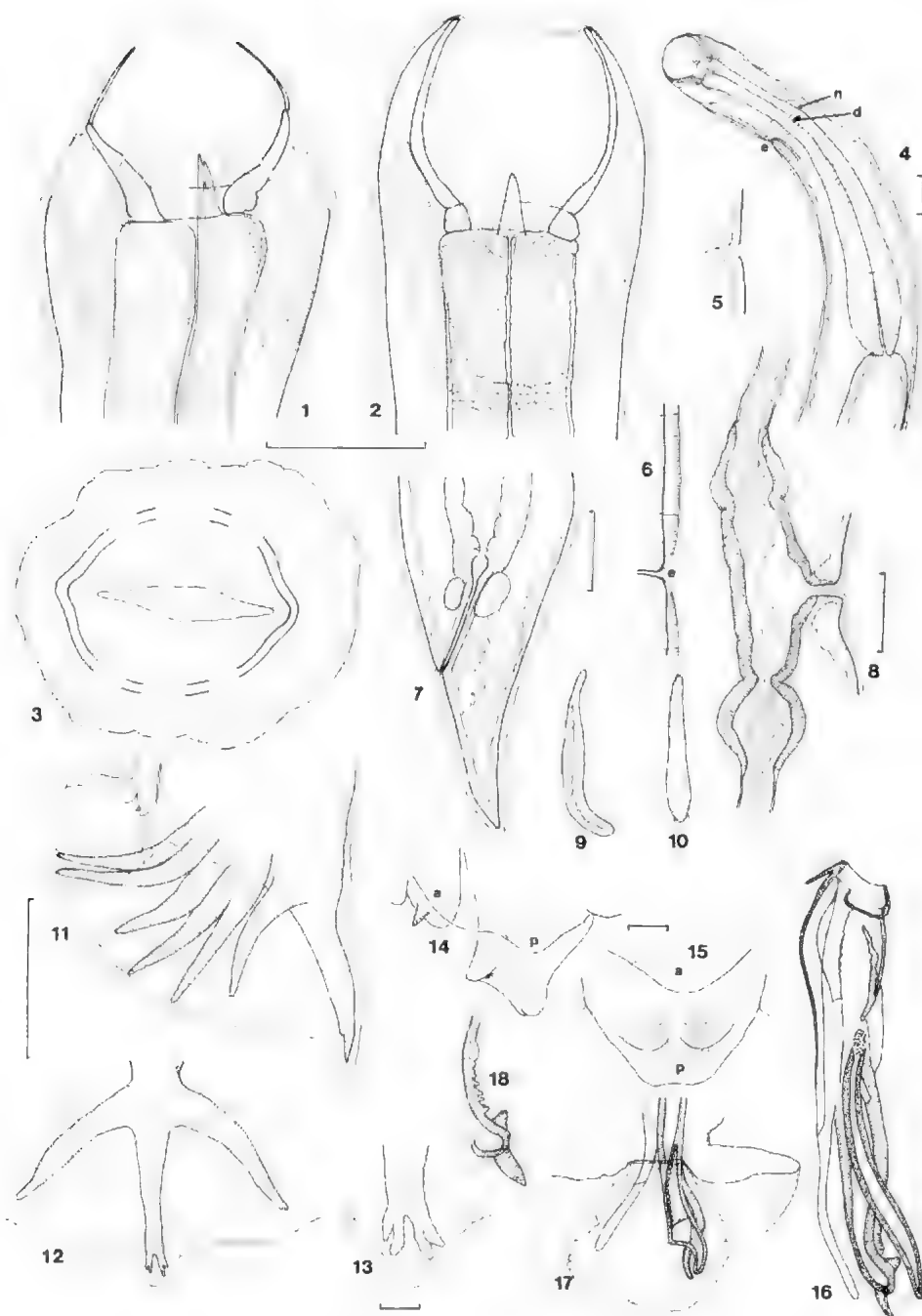
Small nematodes, coiled in loose, flat spiral, ventral surface on inside of coil. Body without longitudinal ridges or alae, covered by numerous transverse striations. Striations extremely fine, close together, interspersed irregularly with more prominent striations, 0.024-0.048 apart. Mouth opening oval, slit-like when closed, dorsoventrally elongate. Lips absent; mouth surrounded by 2 lateral, jaw-like structures joined at dorsal and ventral margins. Each jaw bears 3 finger-like extensions of pulp-tissue which reach mouth opening. Cephalic papillae not seen. Jaws supported posteriorly by U-shaped buttress-like elevations of cuticle and subcuticular tissues on dorsal and ventral aspects, extending from well posterior to anterior extremity of oesophagus, running anteriorly and laterally terminating at origin of 3 extensions of pulp-tissue. Buccal capsule large, urceolate, with thickened rim at base, thinning markedly anteriorly; walls also thin dorsally and ventrally. Single pointed, elongate dorsal tooth arises from oesophagus; subventral teeth absent. Dorsal oesophageal gland opens through apex of dorsal tooth. Oesophagus elongate, clavate, slightly wider at posterior end. Nerve ring encircles oesophagus near anterior extremity. Excretory pore at level of nerve ring. Deirid small, not lobed, at level of excretory pore.

Male

Length 4.9-5.6 (5.2); maximum width 0.25-0.32 (0.28); buccal capsule 0.11-0.13 (0.12) × 0.11-0.13 (0.12); tooth 0.035-0.044 (0.040) long; buttresses arise 0.20-0.23 (0.21) from anterior end; oesophagus 0.78-0.88 (0.82); nerve ring 0.37-0.40 (0.39) from anterior end; excretory pore 0.35-0.38 (0.37) from anterior end; deirids 0.35-0.37 (0.36) from anterior end; spicules 0.26-0.32 (0.29); gubernaculum 0.11 long. Lateral lobes of bursa enlarged, fused with ventral lobes. Dorsal lobe very small, not separated from lateral lobes. Ventroventral and ventrolateral rays separated, slender, each reaching margin of bursa. Lateral rays broad at origin, externolateral, not reaching margin of bursa; other lateral rays reaching margin of bursa. Externodorsal ray slender, originating from dorsal ray, not reaching margin of bursa. Dorsal ray slender, divided into 2 very short branches at distal extremity, each minutely divided at tips. Bullae over origin of lateral and ventral rays absent. Genital cone not prominent. Anterior lip of cone very small, conical, with tooth-like appendage ventrally. Posterior lip gives rise to rounded, distally bifid projection. Spicules short, complex, not heavily sclerotised, yellow. Spicules trifid distally. Main branch of spicule with serrated lateral margin, and bi-cornuate distal extremity. Lateral branch of spicule slender, simple, no longer than medial branches, tip simple. Third branch simple, elongate, poorly sclerotised. Distal tip of spicule with large transparent flange. Gubernaculum slender, elongate.

Female

Length 5.5-6.2 (5.9); maximum width 0.42-0.48 (0.45); buccal capsule 0.12-0.14 (0.13) × 0.13-0.15 (0.14); tooth 0.035-0.050 (0.044); buttresses arise 0.22-0.24 (0.23) from anterior end; oesophagus 0.87-0.98 (0.94); nerve ring 0.35-0.40 (0.37) from



Figs 1-18. *Globocephaloides affinis* Johnston & Mawson.

Fig. 1, Cephalic end, lateral view. Fig. 2, Cephalic end, ventral view. Fig. 3, Cephalic end, *en face* view. Fig. 4, Anterior end, lateral view. Fig. 5, Deirid, ventral view. Fig. 6, Transverse body striations in region of excretory pore. Fig. 7, Female tail, lateral view. Fig. 8, Vulva and ovejector, lateral view. Fig. 9, Gubernaculum, lateral view. Fig. 10, Gubernaculum, dorsal view. Fig. 11, Bursa, lateral view. Fig. 12, Dorsal lobe of bursa, dorsal view. Fig. 13, Termination of dorsal ray, dorsal view. Fig. 14, Genital cone, lateral view. Fig. 15, Genital cone, ventral view. Fig. 16, Spicule, lateral view. Fig. 17, Distal tip of spicule with surrounding cuticular flange, lateral view. Fig. 18, Main branch of spicule showing denticulate margin, lateral view. Scale lines: Figs 1-3, 5, 6, 9-12, 16-18 to same scale, 0.1 mm; Figs 4, 7, 8 to same scale, 0.1 mm; Figs 13-15 to same scale 0.01 mm.

Legend: a, anterior lip of genital cone; d, deirid; e, excretory pore; n, nerve ring; p, posterior lip of genital cone.

anterior end; excretory pore 0.35–0.39 (0.37) from anterior end; deirids 0.37–0.41 (0.39) from anterior end; tail 0.18–0.20 (0.19); vulva to posterior end 1.41–2.10 (1.76); egg 0.08–0.11 (1.10) \times 0.06. Tail short, simple, conical. Vulval lips not prominent; lips approximately equal. Ovejectors paired; vaginae uterinae short. Uteri large, sac-like opposed. Egg thin-shelled, ellipsoidal with two-cells when laid.

Site in host: duodenum.

Globocephaloides macropodis Yorke & Maplestone, 1926

Syn. *Globocephaloides wallabiae* Johnston & Mawson, 1939

Globocephaloides thetidis Johnston & Mawson, 1939

Material examined: From *Macropus agilis*: Qld: 1 ♂, 4 ♀, Townsville, AHC 7565; 1 ♂, 5 ♀, Hervey's Range (Townsville), AHC 7165; 1 ♀, Black River (Townsville), AHC 7515; 2 ♀, Inkerman Station via Home Hill, AHC 7525; 2 ♂, Wenlock River, Cape York, AHC 7407.

From *Macropus dorsalis*: Qld: 14 ♂, 19 ♀, Milman, AHC 12023, 12253; 7 ♂, 12 ♀, Clements Creek, Marlborough, AHC 12199; 2 ♂, 3 ♀, Warrawee Station via Charters Towers, AHC 12743, 11298; 2 ♂, Mt Surprise, AHC 11141; 1 ♂, 6 ♀, Pallamana Station via Charters Towers, AHC 12745; 8 ♂, 16 ♀, Harvest Home Station via Charters Towers, AHC 12744.

From *Macropus parryi*: Qld: 9 ♂, 24 ♀, Inkerman Station via Home Hill, AHC 11931, 12364.

From *Wallabia bicolor*: Qld: 1 ♀, Harvest Home Station via Charters Towers, AHC 12334.

From *Aepyprymnus rufescens*: Qld: 2 ♂, 2 ♀, Ayrsville, AHC 8841.

From *Lagorchestes conspicillatus*: Qld: 6 ♂, 3 ♀, Bohle, AHC 12837.

Amphicephaloides thylogale Beveridge, 1979

Material examined: From *Thylogale stigmatica*: Qld: 1 ♂, 3 ♀, Pearamon, AHC 11235; 1 ♂, 3 ♀, Tolga, AHC 7351; 1 ♂, El Arish, AHC 7383; 17 ♂, 11 ♀, Wongabel State Forest, AHC 12354.

Discussion

Globocephaloides affinis was initially described from the small intestine of *Macropus dorsalis* by Johnston & Mawson (1939) on the basis of female specimens only. Beveridge (1979) considered that the only distinguishing feature of this species, namely the larger buccal capsule, was not a valid specific character given the variation seen in other species, and in the absence of males suppressed *G. affinis* as a synonym of *G. macropodis*. In recent collections from *M. dorsalis*, male and female nematodes with extremely large buccal capsules, similar to the

original description of *G. affinis*, were found in association with *G. macropodis*. The characters of the male copulatory apparatus indicate clearly that *G. affinis* is a valid species and is not synonymous with *G. macropodis*. *G. affinis* possesses a gubernaculum, unlike congeners, lacks bullae overlying the lateral lobes of the bursa, has a much longer dorsal lobe of the bursa and the spicule bears denticulate processes on its main branch. The spicules are lightly sclerotised and yellow in colour, as in *G. macropodis*, but, like *G. trifidospicularis*, they have three distal branches compared with two branches in *G. macropodis*. The presence of two simple subsidiary branches of similar length differs markedly from *G. trifidospicularis* in which the minor branches are sinuous and differ in length. In addition, the genital cone differs from congeners in having a diminutive anterior lip, and a short, stout posterior lip. The simple deirid differs strikingly from the bilobed deirids present in both *G. macropodis* and *G. trifidospicularis*. The presence of a gubernaculum, denticulate spicules, the lack of paired bullae on the internal surface of the bursa, the features of the genital cone, the lack of subventral teeth in the buccal capsule and the presence of a thickened ring at the base of the capsule indicate similarities with *Amphicephaloides thylogale* rather than with congeners. The buccal capsule of *G. affinis* is considerably larger than either *G. macropodis* or *G. trifidospicularis* and appears to be a reliable distinguishing character. Females of *G. affinis* can be distinguished by the size of the buccal capsule, by the absence of prominent vulval lips, and by the extremely fine body striations, interspersed at irregular intervals by coarser striations.

G. affinis occurs commonly in *M. dorsalis* and is frequently found in mixed infections with *G. macropodis* (Table 1). In the Charters Towers area of Qld, *G. affinis* was found in 13 of 14 *M. dorsalis*, one of six *M. giganteus*, none of 21 *M. robustus* and none of five *Wallabia bicolor*, suggesting that *M. dorsalis* is the normal host species, but that it may occasionally infect other sympatric macropodid species.

G. wallabiae Johnston & Mawson, 1939 was placed as a synonym of *G. macropodis* by Beveridge (1979). Initially described from *Macropus dorsalis*, the type specimens have been lost, and in relegating the species to synonymy, Beveridge (1979) relied on new material collected from *M. dorsalis* which consisted of seven specimens only. The frequent occurrence of *G. macropodis* in *M. dorsalis* and careful comparison of this new material with a similarly extensive series of specimens from the type host, *M. agilis*, confirms the synonymy of *G. wallabiae* with *G. macropodis*.

G. thetidis Johnston & Mawson, 1939, was also placed as a synonym of *G. macropodis* by Beveridge (1979). *G. thetidis* had been described originally from a few specimens found in *Thylogale thetis* from the New England region of N.S.W., yet attempts to collect additional specimens of the parasite in New England and in southern Qld yielded only *A. thylogale* (Beveridge, 1979). Other nematode species described from the same host animal from New England from which Johnston & Mawson (1939) described *G. thetidis* suggest that the host has been misidentified. Species of *Rugopharynx* Moennig, 1927, and *Zoniolaimus* Cobb, 1898, originally described from "*T. thetis*" in fact occur only in *M. dorsalis* (Beveridge 1982, 1983). Misidentification of the host would account for the otherwise inexplicable occurrence of *G. macropodis* in *T. thetis*, and the common occurrence of *G. macropodis* in *M. dorsalis* (Table 1) therefore supports the synonymy of *G. thetidis* with *G. macropodis*.

G. macropodis has previously been reported from *M. agilis*, *M. dorsalis*, *M. giganteus* and *Petrogale inornata* in Qld (Beveridge 1979; Speare *et al.* 1983). Data presented in this paper confirm that *G. macropodis* is a common parasite of *M. dorsalis*. The failure to find *G. macropodis* in *M. giganteus* (Table 1), even when *M. giganteus* was sympatric with other infected macropodid species, suggests that it is only an incidental parasite of this host. Beveridge (1979) found only a single female *G. macropodis* in *M. giganteus* near Rockhampton. *G. macropodis* is reported for the first time from *Aepyprymnus rufescens*, *Macropus parryi*, *Lagorchestes conspicillatus* and *Wallabia bicolor*, but in each instance the prevalence is relatively low, sug-

gesting that they are incidental hosts, while *M. agilis* and *M. dorsalis* are the principal hosts of this nematode species (Table 1).

Beveridge (1979) concluded that both *G. trifidospicularis* and *G. macropodis* have an extremely wide host range, the former species occurring in southern Australia and being replaced by *G. macropodis* in the north. The recent collections support this view; *M. parryi*, *M. giganteus* and *W. bicolor* are hosts of *G. trifidospicularis* in Victoria and N.S.W. (Beveridge 1979), while in northern Qld the same host species are parasitised, if infrequently, by *G. macropodis*. By contrast, *G. affinis* is apparently restricted to *M. dorsalis*, with only an occasional infection in *M. giganteus* in areas where the two macropodid species are sympatric. *A. thylogale* occurs in *Thylogale thetis* in N.S.W. and southern Qld and in *T. stigmatica* from northern N.S.W., but has not been reported previously in *T. stigmatica* from northern Qld where it is apparently restricted to this host species.

To date, only *G. trifidospicularis* has been implicated in causing disease in kangaroos (Arundel *et al.* 1977). One of us (R.S.) has recently autopsied a 12 month old captive *M. giganteus* which died from anaemia and hypoproteinaemia caused by 2,300 *G. macropodis*. The juvenile *M. giganteus* grazed a confined area together with adult *M. agilis* and *M. parryi*, indicating that under confined conditions, *G. macropodis* as well as *G. trifidospicularis* can be a serious pathogen.

Acknowledgments

Our thanks are due to P. Speare for assistance in collecting and examining specimens.

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ADDITIONS TO THE COLLEMBOLIAN FAUNA OF THE ANTARCTIC

BY PENELOPE GREENSLADE & K. A. J. WISE

Summary

Two new species records of Collembola from Deception Island are noted. *Onychiurus* sp., and *Folsomia candida*. A description is given for the former. Neither of the two genera have been recorded previously from the Antarctic. A discussion on their possible recent introduction to the island is given.

ADDITIONS TO THE COLLEMBOLAN FAUNA OF THE ANTARCTIC

by PENELOPE GREENSLADE* & K. A. J. WISE†

Summary

GREENSLADE, P. & WISE, K. A. J. (1984) Additions to the collembolan fauna of the Antarctic. *Trans. R. Soc. S. Aust.* **108**(4), 203–205, 13 December, 1984.

Two new species records of Collembola from Deception Island are noted, *Onychiurus* sp., and *Folsomia candida*. A description is given for the former. Neither of the two genera have been recorded previously from the Antarctic. A discussion on their possible recent introduction to the island is given.

KEY WORDS: Collembola, taxonomy, Antarctic, Deception Is., introduced species.

Introduction

Wise (1967, 1971) recorded 16 species of Collembola from Antarctica, (the mainland together with nearby offshore islands, including the South Shetland islands, which lie at 61–62° S). Re-examination of two collections made by J. Strong on Deception Island (South Shetlands) in 1965, revealed two previously unrecognised species representing the genera *Onychiurus* and *Folsomia*, not previously recorded from the Antarctic. The species from these collections are listed in Table 1 and the new records given in more detail below.

Family Onychiuridae

Onychiurus sp.

FIG. 1

Material examined 7 ♀♀, 1 ♂ 1 imm. (mntd) SAMA, 1 ♀ (mntd) BPBM, 1 ♂ (mntd) AMNZ, 40 spec. (alc) BPBM, 1 spec. (alc) SAMA, South Shetlands, Deception Island, Whalers Bay, under whale bones on beach, 3.ii.1965, J. Strong; same locality and date, under whale bones and debris on beach, 1 ♀ (mntd) AMNZ, 2 spec. (alc) BPBM. **Description:** Body length: ♀♀ 1.5–1.6 mm, ♂ 1.2 mm. Colour: white (after preservation).

Post-antennal organ consisting of many simple vesicles in two parallel rows; pseudocelli pattern 33, 022, 333330, with slight variation (i.e. antennal base pseudocelli 4, 3 in one of the specimens examined); seta m on thorax 1 present; subcoxae II and III without pseudocelli; claw without tooth, empodial appendages with narrow lamellae; ventral tube with 10 + 10 setae; anal spines present and single furcal remnant with 2 setae; abdomen V with s' seta anterior to S seta, macrochaetae about twice anal spines in length; abdomen VI with slightly divergent lateral setae and a single median seta (Fig. 1)

Distribution of such characters as the pseudocelli and setal patterns within the population is difficult to analyse because of the poor state of preservation of the material and prevents identification to species. Using Fjellberg's (1980) key the animals are near to the Arctic littoral species, *O. islandicus* Gisin although the s' seta is situated more anteriorly in the Antarctic species. We consider the present species to be a member of the *armatus* group. Controversy over the specific value of characters has led to both a proliferation of species names in the genus and a number of synonymies (Gisin 1960, Hale & Rowland 1977, Pitkin 1980).

This is a new record for *Onychiurus*. The specimens were previously misidentified as *Tullbergia mixta* Wahlgren (Wise 1971), however the identity of other records of *T. mixta* from Deception Island by Gressitt *et al.* (1963) and Wise (1967) have been confirmed (K.A.J.W. det. 1983).

Family Isotomidae

Folsomia candida Willem

Material examined 1 imm. (mntd) BPBM, South Shetland Islands, Deception Island, Whalers Bay,

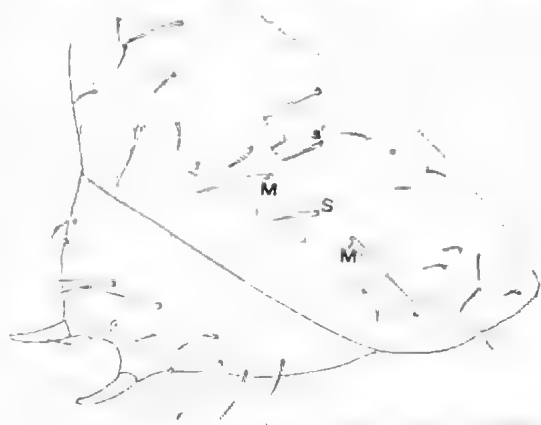


Fig. 1. Dorsal view of abdomen V and VI of ♀ showing pseudocelli and chaetotaxy, M = macrochaeta, s' S = sensory setae. Scale line = 100 µ.

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TABLE 1. *Collembola* collected from Deception Island 1965. C=Cosmopolitan species, N=Native species

Collection Data	Species	Distribution	Published Records of Specimens
Whale Bay, under whale bones on beach 3.ii.1965.	Hypogastruridae		
	<i>Hypogastrura viatica</i> (Tullb.)	C	Wise, 1967: 129 (2 specimens)
	Onychiuridae		this work (recorded in error as <i>Tullbergia mixta</i> Wahlgren by Wise, 1971: 59)
	<i>Onychiurus</i> sp. J. Strong	? C	
Whale Bay, under whale bones and debris on beach 3.ii.1965, J. Strong	Isotomidae		
	<i>Cryptopygus antarcticus</i> Willem	N	Wise, 1971: 65
	<i>Cryptopygus caecus</i> Wahlgren	N	this work
	Hypogastruridae		
	<i>Hypogastrura viatica</i>	C	Wise, 1967: 129 (1 specimen)
	Onychiuridae		this work (recorded in error as <i>Tullbergia mixta</i> by Wise, 1971: 59)
	<i>Onychiurus</i> sp.	? C	
	Isotomidae		
	<i>Folsomia candida</i> Willem	C	this work
	<i>Archisotoma brucei</i> (Carpenter)	N	Wise, 1967: 137
	<i>Cryptopygus antarcticus</i>	N	Wise, 1971: 65
	<i>Cryptopygus caecus</i>	N	this work (2 imm. specimens) Other collections from Deception Is. recorded Wise, 1967: 136

under whale bones and debris on beach, 3.ii.1965, J. Strong.

Although the specimen is immature, it is of adult size, (1.8 mm) and agrees in all respects with Stach's 1947 redescription of the species and with other reliably identified specimens.

Six species were found in the two collections made by Strong (Table 1) and this is a rich fauna for a species poor environment such as the Antarctic. The reason for this could be the high level of decaying organic matter which was almost certainly present. It is usual for temporary habitats of this type to be colonised by widely distributed *r* selected species (Greenslade & Greenslade 1983).

Discussion

Both *Onychiurus* and *Folsomia* are most highly diverse in the Northern Hemisphere with many species in and near the Arctic Circle. The southern hemisphere equivalents of these two genera are probably *Tullbergia* and *Cryptopygus* respectively, which dominate antarctic faunas both in numbers of individuals and species. In Australia *Onychiurus* is found predominately in disturbed humid habitats; it is rare in native vegetation. In contrast *Tullbergia* species of the southern *antarctica* Lubbock and *mixta* groups are restricted to soils which have retained their native vegetation cover. It is likely that all *Onychiurus* species in Australia have been introduced while species belonging to these groups of *Tullbergia* are native.

Onychiurus had not been found previously further south than Campbell Island (52° 33'S) where *O. subantarcticus* Salmon 1949 has been recorded from a disturbed habitat. *Onychiurus* species of the *armatus* group until now had been recorded on every continent but Antarctica. *Folsomia candida* is a species also found on every continent up to the present except Antarctica but is not abundant. Both species are easily cultured in the laboratory with plentiful food and moist conditions and can mount dense populations under these conditions.

It seems likely from this and other distribution records that both the *Cryptopygus* species and *Archisotoma brucei* are native to the area while the *Onychiurus* and *Folsomia* may be relatively recent introductions. *Hypogastrura viatica* is a widely distributed species in the southern hemisphere including other subantarctic islands but, because there are no endemic congeners in the Australasian Region, (all species which have been found so far also occur in Europe), it is possible that this species also is not native to the region. What is known of the biology of this and the other genera would tend to support these conclusions. There is evidence for the recent introduction of another *Hypogastrura* species to a subantarctic island. *Hypogastrura denticulata* (Bagnall) was collected for the first time on Macquarie Island in 1974 despite intensive earlier collecting there in the 1960's. The collecting site was a rubbish dump near the biology hut. Since that year *H. denticulata* has been collected from a number

of different areas on the island (P. Greenslade & K. A. J. Wise, unpubl.).

Further collecting on Deception Island is needed to determine whether *Onychiurus* and *Folsomia* have become established.

Acknowledgments

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FIRST REPORTED TRILOBITES FROM THE LOWER CAMBRIAN NORMANVILLE GROUP, FLEURIEU PENINSULA, SOUTH AUSTRALIA

BY J. B. JAGO, B. D. DAILY, C. C. VON DER BORCH, A. CERNOVSKIS & N. SAUNDERS

Summary

Two recently discovered fragmentary trilobites are the first found from the Lower Cambrian Normanville Group of Fleurieu Peninsula, South Australia. They occur about 340 metres above the base of the Heatherdale Shale, the uppermost unit of the Normanville Group. An exact age within the Early Cambrian cannot be given on available evidence although a middle Early Cambrian age seems likely. The species represents one of the earliest members of the Conocoryphidae. The trilobites are associated with probable conchostracans. Trace fossils and possible desiccation (?synaeresis) cracks are present within the Heatherdale Shale just below the trilobite-bearing horizon.

FIRST REPORTED TRILOBITES FROM THE LOWER CAMBRIAN NORMANVILLE GROUP, FLEURIEU PENINSULA, SOUTH AUSTRALIA

by J. B. JAGO[‡], B. D. DAILY[†], C. C. VON DER BÖRCH, A. CERNOVSKIS & N. SAUNDERS

Summary

JAGO, J. B., DAILY, B., VON DER BÖRCH, C. C., CERNOVSKIS, A., SAUNDERS, N. (1984). First Reported Trilobites from the Lower Cambrian Normanville Group, Fleurieu Peninsula, South Australia. *Trans. R. Soc. S. Aust.* **108** (4), 207-211, 13 December, 1984.

Two recently discovered fragmentary trilobites are the first found from the Lower Cambrian Normanville Group of Fleurieu Peninsula, South Australia. They occur about 340 metres above the base of the Heatherdale Shale, the uppermost unit of the Normanville Group. An exact age within the early Cambrian cannot be given on available evidence although a middle Early Cambrian age seems likely. The species represents one of the earliest members of the Conocoryphidae. The trilobites are associated with probable conchostracans, trace fossils and possible desiccation (?synaeresis) cracks are present within the Heatherdale Shale just below the trilobite-bearing horizon.

KEY WORDS: Sellick Hill, Fleurieu Peninsula, Heatherdale Shale, Normanville Group, trilobites, Conocoryphidae, Early Cambrian.

Introduction

The purpose of this work is to report the discovery of trilobites from the Heatherdale Shale in the Sellick Hill area, 55 km south of Adelaide. The two specimens figured herein represent the first trilobites known from the Normanville Group (Daily & Milnes 1973). The Normanville Group, which rests unconformably on the late Precambrian Adelaidean Marino Group, comprises the Mt Terrible Formation (base), Wangkonda Formation, Sellick Hill Formation, Fork Tree Limestone and Heatherdale Shale (top). It is overlain sharply but conformably by the Carrickalinga Head Formation, the basal member of the Kanmantoo Group. In the Sellick Hill area the Normanville Group is commonly overturned (Fig. 1), with the finer grained units showing a prominent cleavage.

Early Cambrian Archaeocyatha were first reported from what is now known as the Fork Tree Limestone at Sellick Hill by Howchin (1897). Abele & McGowran (1959) gave a brief summary of pre-1959 work in the Sellick Hill area. Since 1897 numerous fossils have been reported from all members of the Normanville Group by various workers (e.g. Abele & McGowran 1959; Daily 1963, 1969, 1976a; Daily *et al.* 1976, 1982; Wright 1969), including archaeocyathids, hyolithids, gastropods, sponges, brachiopods, tommotiids and others.

The Heatherdale Shale (Abele & McGowran 1959) comprises a lower calcareous member and an upper dark grey to black shale and siltstone, generally lacking in carbonate. Nodules and stringers of

black phosphate occur, and are particularly conspicuous in the upper member (Daily *et al.* 1976). Lateral and vertical changes in carbonate content within the formation are quite marked (Daily 1963; Daily *et al.* 1976). Hyolithids, sponges, brachiopods and gastropods occur sparsely throughout the Heatherdale Shale.

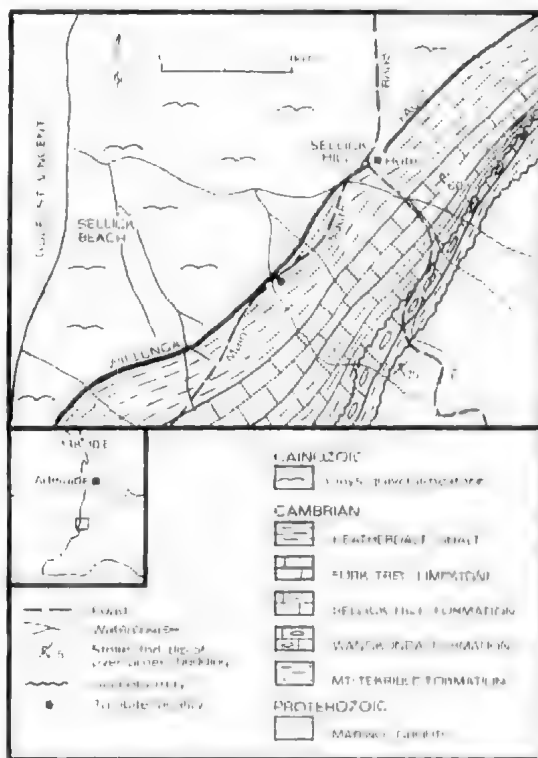


Fig. 1. Geology of the Sellick Hill area, showing the trilobite locality.

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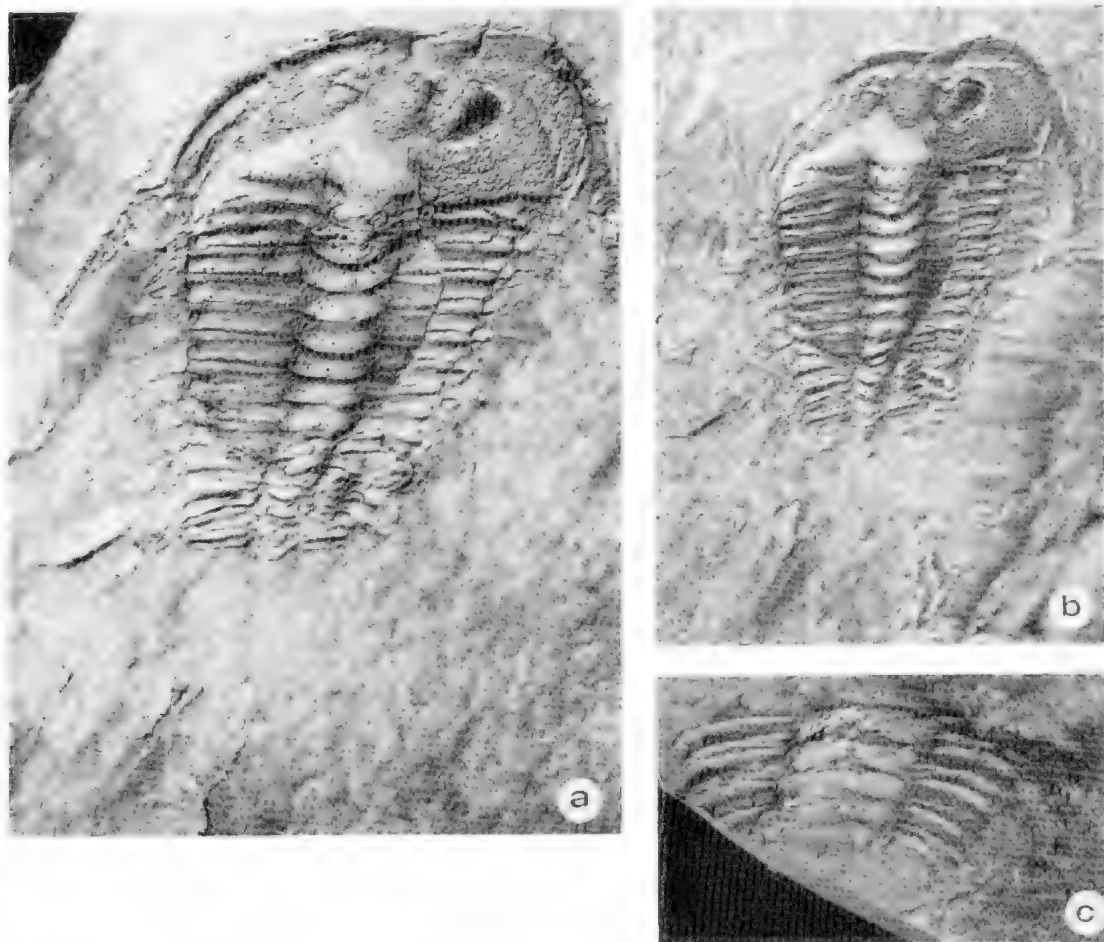


Fig. 2. a. P24321a, latex cast of external mould of conecoryphid trilobite, X3. The spine bases on the axial rings of the thorax probably supported spines of a length about equal to half the width of the axial ring. b. P24321b, internal mould of conecoryphid trilobite, X2. c. P24322a, latex cast of external mould of second trilobite specimen, X3.

In February 1983, the first trilobite (Figs 2a, b) from the Normanville Group, was found by three of us (C. C. V. B., A. C., N. S.) in the upper member of the Heatherdale Shale about 340 metres above the base of the formation in a road cutting on the Main South Road (Fig. 1). Subsequent searches by all authors have yielded only one further specimen (Fig. 2c). Abundant specimens of what are probably small conchostracan arthropods are found at the same stratigraphic level, where they occur mainly in small black phosphate-rich nodules. Organic-walled microfossils have also been found in the Heatherdale Shale (Foster *et al.* 1985). Abundant trace fossils (Fig. 3) are known in several horizons one to two metres below the level where the trilobites were found. This is the first record of trace fossils from the Heatherdale Shale.

Possible desiccation cracks (Fig. 4) are present about 2 metres below the trilobite horizon. If these are indeed desiccation cracks, rather than synaeresis cracks, then this suggests a very shallow water marine depositional environment for this part of the Heatherdale Shale. However, it should be noted that the Early and Middle Cambrian conocoryphids in eastern North America are characteristic of faunas found some distance offshore (Lochman-Balk & Wilson, 1958).

Palaeontology

Both available trilobites are preserved as external and internal moulds. They are described briefly below. The specimens figured herein are housed in the palaeontology collection of the South Australian Museum.

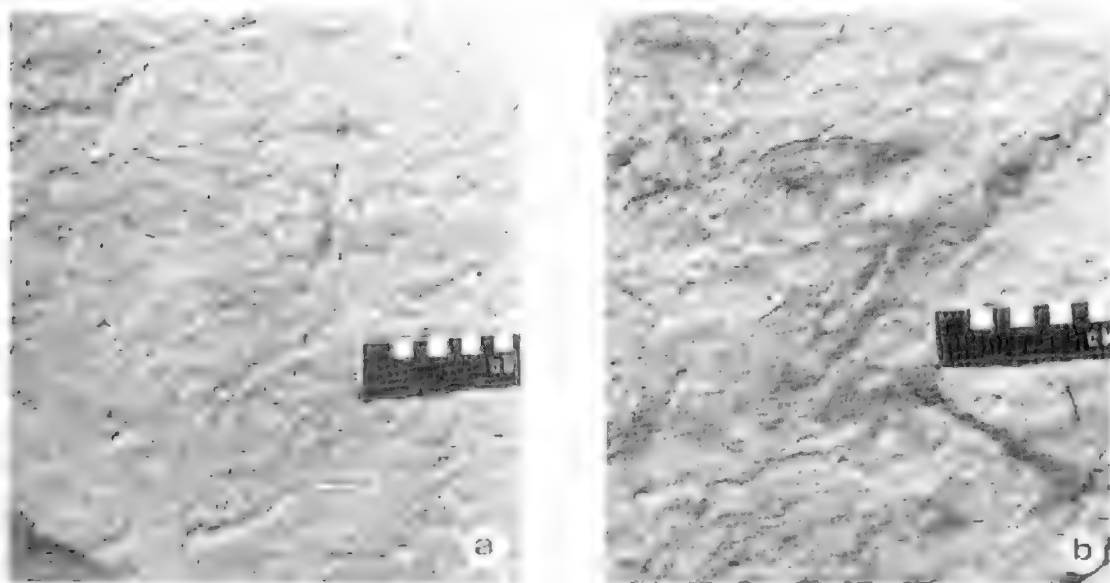


Fig. 3a, b. Trace fossils in an horizon one to two metres below the level of the trilobites.



Fig. 4. Desiccation(?) or synaeresis (?) cracks, Heatherdale Shale, about 2 metres below the level of the trilobites.

Specimen 1

Description: The first specimen (P24321a + b, Figs 2a, b) is distorted and crushed; it comprises a cephalon, a hypostome and parts of thirteen thoracic segments. The surface is coarsely granulate with exception of the pleural furrows. Before distortion the cranidium was wider than long. The border furrow is moderately deep; the border is narrow. The genal spines extend posteriorly to at least opposite the fifth thoracic segment. The glabella is narrow; but the preservation makes it difficult to determine just how far forward it extends. The occipital furrow is moderately deep abaxially, but very shallow across the centre of the glabella. Other details of the glabella are obscured by poor preservation, although near the front of the glabella is a short furrow which is directed abaxially and posteriorly. Narrow, low eye ridges extend from the glabella almost to the border furrow. Although facial sutures appear to be absent, it is difficult to be certain of this due to the poor preservation. The shape of a small hypostome shows up on the right hand side of the anterior part of the cephalon where the shell of the cephalon has been crushed against the underlying hypostome.

Parts of 13 thoracic segments are preserved. Each segment is about 11 times as wide as is long. The axis has a width about 0.3 that of the segment (excluding pleural spines). There is a large centrally placed spine base on each axial ring. Wide pleural furrows deepen abaxially; the pleural strips are narrow and granulate. The pleural spines are long and

narrow with the spine on the eleventh thoracic segment being extraordinarily long and extending well to the posterior of the projected position of the pygidium. It is similar to the very long pleural spine on the eleventh thoracic segment of the late Middle Cambrian conocoryphid, *Dasometopus maensis* Korobov (1973, pl. 5, fig. 1).

Specimen 2

Comments: This specimen (P24322a + b, Fig. 2c) comprises parts of several posterior thoracic segments as well as part of a very poorly preserved pygidium. This specimen probably belongs in the same species as Specimen 1, but does not warrant further description.

Discussion: The specimens probably belong to a new genus of the Conocoryphidae, although they are too poorly preserved to make an accurate assessment. One of us (B.D.) has collected what may be a representative of the same conocoryphid genus in association with other polymerids and an eodiscid from the upper part of the Parara Limestone in the Chace Range of the Flinders Ranges. When this material is studied it may assist in positively identifying the specimens from the Heatherdale Shale. The specimens described herein belong in the Conocoryphidae and add to the rather limited number of Conocoryphidae reported from Lower Cambrian sediments. As noted below, the Heatherdale Shale is of Early Cambrian age, whereas most known Conocoryphidae are of Middle Cambrian age.

However, the conocoryphid genera *Pseudatops* and *Atops* are known from the upper part of the Lower Cambrian of eastern North America (Lochman-Balk & Wilson 1958, fig. 4). *Pseudatops* is also known from England and Wales where it is found in the "Protolenid-Strenuellid" Zone of Cowie *et al.* (1972) which is regarded as of late Early Cambrian age by Cowie *et al.* (1972) and Rushton (1974).

Korobov (1966) described two new genera of conocoryphids, *Atopina* and *Ivshiniellus* from the Lower Cambrian Aldanian Stage of Tuva. Korobov (1973, tables I and II) suggested that all known Early Cambrian Conocoryphidae are of approximately the same age, equivalent to the upper part

of the Aldanian Stage. Fritz (1973) reported a conocoryphid from the middle Lower Cambrian of north-western Canada. Further discussion on the subject of Early Cambrian conocoryphid correlations is reserved until two of us (B.D. and J.B.J.) describe the material mentioned above from the Flinders Ranges.

Age of the Heatherdale Shale

The two trilobite specimens figured herein are so poorly preserved as to preclude formal description and adequate comparison with known taxa, and hence are of limited biostratigraphic use. However, as noted above, a conocoryphid trilobite is known from the Parara Limestone in the Flinders Ranges. Daily (1972, 1976a) has shown that the Parara Limestone is of Atdabanian age within the Early Cambrian.

The Fork Tree Limestone, which conformably underlies the Heatherdale Shale, comprises two members, the lower one of which contains abundant, but poorly preserved archaeocyathids. D. Gravestock (pers. comm.) has identified the following archaeocyathids:—*Ajacicyathus sellicksi*, *Dokidocyathus* and *Pycnoidocyathus*, but notes that because all are long ranging genera an exact age within the Early Cambrian cannot be given.

A correlation chart given by Daily (1976b) suggests that the Heatherdale Shale is stratigraphically well below the late Early Cambrian fossiliferous sequences exposed on the north coast of Kangaroo Island as described by Daily *et al.* (1979). Hence at this time on the basis of fossil evidence it is not possible to give a more precise date to the Heatherdale Shale than "somewhere in the middle part of the Early Cambrian". Suggested Early Cambrian correlations within southern Australia are given in Cooper & Grindley (1982).

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We wish to thank J. Shergold (Bureau of Mineral Resources, Canberra), R. Jenkins (University of Adelaide), P. Jell (National Museum, Melbourne), A. R. Palmer (Geological Society of America, Boulder) and C. B. Foster (Western Mining Corporation, Adelaide) for valuable advice and discussion.

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LEAF MARKING IN RANGELAND GRAZING STUDIES

BY R. T. LANGE

Summary

Sheep graze extensive areas of arid zone vegetation in South Australia. A simple leaf-marking technique is described that provides a quick and novel method of assessing the grazing pressure.

LEAF MARKING IN RANGELAND GRAZING STUDIES

Sheep graze extensive areas of arid zone vegetation in South Australia. A simple leaf-marking technique is described that provides a quick and novel method of assessing the grazing pressure.

On saltbushes (*Atriplex vesicaria*) it is quick and simple to mark hundreds of the outer leaves each with a paint-dot about 2 mm in diameter and to provide for rapid reinspection of the dots by painting guidemarks on the bushes' stems.

Free grazing sheep are colourblind¹ and graze the marked leaves along with the rest, showing no bias for or against marked leaves provided that the dots are small and odourless. That was shown by 5 trials in each of which approximately 200 random shoots were marked and 200 more were photographed before exposure to six weeks of pastoral grazing. Contingency tables of the results (as in table 1 for example) were all non-significant. Fenced-off control marked shoots showed no losses.

TABLE 1. Contingency table comparing sheep grazing losses of physically tagged (painted) and untouched (photographed) leaves on saltbushes. $\chi^2 = 0.05$ which is non-significant, showing that sheep did not graze painted leaves differently to non-painted leaves.

		after 6 weeks		
		missing	remaining	totals
initially	painted	30	174	204
	photographed	33	173	206
	totals	63	347	410

So this technique establishes, for each locality where a large number of leaf-dots is deployed, the likelihood of an outer shoot of the saltbush being grazed during any month or similar period (the percentage chance of being grazed).

To illustrate these likelihoods a uniform saltbush plain was studied near Whyalla, South Australia, where 3 sheep-stocked paddocks shared a fence-line T-junction. The paddocks totalled about 5000 ha and had independent flocks of about 275 sheep each (6 ha sheep⁻¹). Quadrats 60 x

4 m were marked in each paddock near the T-junction and 200 leaves were marked on the saltbushes on each, as follows.

All bushes on the quadrat were numbered and were selected by random numbers. On large bushes 10 leaves were marked and on small bushes 5. Each leaf was on a separate terminal shoot of the outermost foliage. Terminal shoots were selected to scatter the marked leaves over the bush. The paint used was yellow quick-drying enamel.

The quadrats were then picked clean of egesta and were left for 6 weeks, when the marks were recounted and the egesta weighed that had fallen on each quadrat during the period. Fig. 1 shows the results.

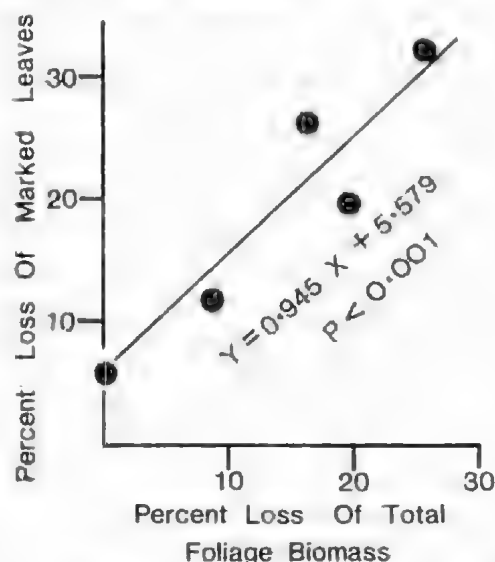


Fig. 2. Percent loss of marked saltbush leaves versus percent loss of total foliage biomass in a small-paddock grazing trial. The samples were 10 x 10 m areas within a 10 x 200 m paddock which sheep grazed unevenly for a week.

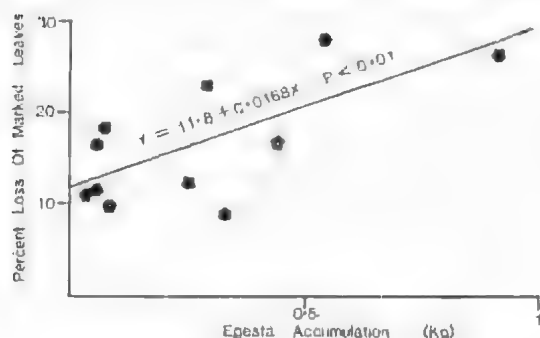


Fig. 1. Percent of marked saltbush leaves taken versus sheep egesta accumulated over a six-week period at each of 11 localities in saltbush vegetation. Further explanation is in the text.

As can be seen, the likelihoods were in the surprisingly high range 8–28% and much of the variation from quadrat to quadrat could be accounted for by quadrat egesta accumulation, which is known from other studies² to index flocktime. From this it should be clear that the marking technique has much potential for use in rangeland studies. As further examples, Fig. 2 shows that percentage loss of marked leaves correlates with percent loss of total foliage biomass³ in small-paddock experimental work, where it is also accounted for in terms of sheep egesta accumulation (Fig. 3).

The following caution must be heeded. Care when applying the paint dots is essential. Experience with this technique in the hands of students shows that spillages on foliage and dots bigger than prescribed can result in sheep avoiding the marked leaves.

The particular value of this technique is that it allows much more sensitive discrimination of the depredations

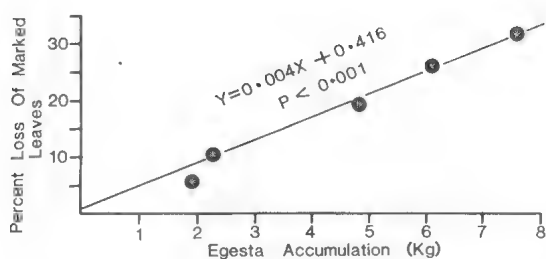


Fig. 3. Percent loss of marked saltbush leaves versus sheep egesta accumulated in a small-paddock grazing trial similar to that described in Figure 2.

of sheep on saltbush than is otherwise possible. The error terms associated with plant biomass estimation techniques, which are the only alternatives, are in general very great³.

¹Huxley, J. (1972) *"Memories I"* (Penguin Books: London).

²Lange, R. T. (1983) *Trans. R. Soc. S. Aust.* 107, 137.

³Andrew, M. H., Noble, I. R. & Lange, R. T. (1979) *Aust. Rangel. J.* 1, 225-231.

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RANGE EXTENSIONS OF REPTILES IN SOUTH AUSTRALIA

T. D. SCHWANER

Summary

The ranges of some reptile species already known to occur in South Australia have been greatly extended by recent field studies. Here we report these findings and briefly comment on their significance.

RANGE EXTENSIONS OF REPTILES IN SOUTH AUSTRALIA

The ranges of some reptile species already known to occur in South Australia have been greatly extended by recent field studies. Here we report these findings and briefly comment on their significance.

Voucher specimens reported here are located in the following museum collections: National Museums of Victoria (NMV); South Australian Museum (SAM). The nomenclature follows Cogger¹ except for *Gehyra purpurascens* (*sensu* Storr).

Family: Gekkonidae. *Gehyra purpurascens* Storr.

Locality record: S. Aust. SAM R24001, Clayton Bore, Cordillo Downs Stn (29°17'S, 138°23'E).

Comments: Storr² reported the distribution of *G. purpurascens* as the arid interior of Western Australia, central and southern Northern Territory and northern S.A. The species is distinct chromosomally from all other *Gehyra* (C. Moritz, *in litt.*, 7.1.1982). Moritz (pers. comm.) has collected another specimen recently from McDouall Peak Stn, S.A. (29°50'S, 134°54'E). These records represent extensions of the range of the species well into central S.A.

Family: Scincidae. *Egernia cunninghami* (Gray).

Locality records: S. Aust. SAM R16989, R17355, R22293-97, West Island (35°37'S, 138°36'E); SAM R17352, AM R93474, Fisheries Beach (35°40'S, 138°07'E); SAM R17354, Deep Creek (35°36'S, 138°15'E); SAM R17353, Blowhole Creek (35°38'S, 138°10'E).

Comments: In S. Aust. this species was known only from the western slopes of the Mt. Lofty Ranges.^{3,4} Specimens were collected around the coast of Fleurieu Peninsula from Cape Jervis to West Island. The West Island specimens represent the only known offshore island population of this species in Australia. Paton & Paton listed the species as occurring on West Island, but apparently were unaware of the uniqueness of the population, and no voucher specimens were collected. These coastal, cliff-dwelling populations are smaller in adult body size and more brightly patterned than inland populations in S.A. In this respect they resemble specimens from the Moonbi Ranges in N.S.W. and might represent a new subspecies (G. Shea & R. Sadler, *in litt.*, 3.1.1984).

Lerista microtis arenicola Storr

Locality records: S. Aust. SAM R21896, Navis Archipelago, Goat Island (32°19'S, 133°30'E); SAM R25088, Franklin Island West (32°27'S, 133°40'E).

Comments: These are new records of *L. m. arenicola* from offshore islands of S. Aust. Previously, two specimens (SAM R1599 and R5860) were collected from "West Coast, S.A." by "Constable Holfforan, Fowler's Bay" on "15.viii.1930" and from "Head of Bight, S.A." in coastal sand hills by "H. Bowshall" on "1.vii.1964" respectively. The Goat Island specimen was collected from under a flat limestone rock near the centre of the island. The Franklin I specimen was found in sand under an uprooted shrub. Although the island specimens conformed to previous descriptions⁵, with nostrils in contact and 23 scale rows at

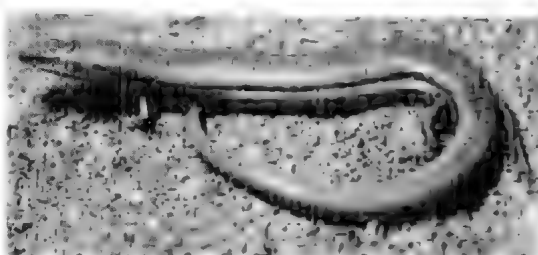


Fig. 1. *Lerista microtis arenicola*.

midbody, the dorsal pattern consisted of two bold dusky lateral stripes, two narrower paravertebral stripes and a narrower vertebral stripe (Fig. 1), similar to the specimens of *L. m. microtis* from Israelite Bay, W.A.⁶

Menenia greyi Gray

Locality records: S. Aust. NMV D56669-71, Kangaroo Island, Smith Creek valley between Ennis Bay and Cape Cassini, 8 km WSW Ennis Bay township (35°38'S, 137°25'E); SAM R23601-05, 1 km E. Prospect Hill/Penneshaw Rd nr Salt Lagoon (35°50'S, 137°47'E); SAM R23635-44, Dudley Conservation Park nr "Sandhurst" (35°51'S, 137°51'E); SAM R23547, R25236, Kingscote (35°39'S, 137°39'E).

Comments: The first specimens of *M. greyi* from Kangaroo Island were collected from under flat stones along Smith Creek (Hutchinson, *in litt.*, 30.vii.1983). Additional specimens subsequently were collected under rubbish and among natural litter from three other widespread localities on the island. One individual was observed (but not captured) in the northwest end of the island at "Harvey's Return" (35°45'S, 136°38'E). Thus, this small, common but elusive skink may have an island wide distribution. Hutchinson (*in litt.*, 30.vii.1983) noted that most *M. greyi* from KI exhibited 24 longitudinal rows of scales at midbody, similar to those reported from Fleurieu Peninsula and different from the modal number (22) reported for other populations.

Family: Elapidae. *Demansia psammophis* (Schlegel)

Locality record: S. Aust. SAM R23753, Kingscote, Kangaroo Island (35°39'S, 137°38'E).

Comments: This first reported specimen of the yellow-faced whipsnake from KI was collected from under a sheet of galvanized iron in the yard of a Kingscote residence. The subadult female (snout-to-vent length = 303 mm) was similar in scalation and colour pattern to mainland specimens of *D. psammophis*.¹ The lone occurrence of this diurnally active snake, and the failure to locate additional specimens in recent intensive searches, suggests that this record may represent a recent, accidental introduction from the mainland.

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- ⁴—— (1976). *Ibid.* 8(2), 5-13.
- ⁵Paton, J. B. & Paton, D. C. (1977). *Corella* 1, 65-76.
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REPTILES NEW TO THE FAUNA OF SOUTH AUSTRALIA

BY T. D. SCHWANER

Summary

Distributions of many reptiles in South Australia are poorly known, in spite of several attempts to document their ranges. Recent fieldwork and re-examination of old specimens lodged in the South Australian Museum and elsewhere, have resulted in the discovery of nine species and subspecies not previously recorded from the State. Here we report these findings and briefly comment on their significance.

REPTILES NEW TO THE FAUNA OF SOUTH AUSTRALIA

Distributions of many reptiles in South Australia are poorly known, in spite of several attempts to document their ranges.^{1,2} Recent fieldwork and re-examination of old specimens lodged in the South Australian Museum and elsewhere, have resulted in the discovery of nine species and subspecies not previously recorded from the State. Here we report these findings and briefly comment on their significance.

The voucher specimens reported here are located in the following museum collections: Australian Museum (AM); South Australian Museum (SAM); Western Australian Museum (WAM). The nomenclature follows Cogger³, except for *Ctenophorus maculatus dualis* (sensu Storr⁴ and Storr *et al.*⁵).

Family: Dicroglossidae. *Diplodactylus williamsi* Kluge.

Locality records: S. Aust: SAM R18117A-B, R28228, Dangali Cons. Park nr. Morganville HS (33°14'S, 140°42'E); SAM R18119A-D, 4 km S Canopus HS (33°33'S, 140°42'E); SAM R18120A-C, 20 km S Canopus HS (33°40'S, 140°42'E); SAM R15042, Bafah Sin (33°39'S, 139°55'E); SAM R16101, nr. Canopus Stn (33°45'S, 140°37'E); SAM R21362, 20 km N Renmark (34°02'S, 140°45'E); SAM R16097, R17127, Dangali Cons. Park (33°41'S, 140°33'E); SAM R9915, Taldra R., Foxton (34°27'S, 140°34'E); SAM R16297, nr. Birthday Dam (33°20'S, 140°54'E).

Comments: *D. williamsi* was found primarily under the bark of fence posts in the riverland and mallee country near Renmark, S.A., a range extension of some 800 km along the River Murray drainage from N.S.W.⁶ Subsequently, specimens of *D. williamsi* in the S.A. Museum from the same or nearby localities were found to be misidentified as *D. intermedius*. *D. williamsi* is distinguished from *D. intermedius* in S.A. by fewer and more irregularly spaced tubercles on the dorsum and by a lack of enlarged scales between the rows of tubercles on the tail (Fig. 1A).

Family: Agamidae. *Ctenophorus maculatus dualis* Storr.

Locality records: S. Aust: SAM R22983, 17 km E of the W.A.-S.A. border (31°35'S, 129°40'E).

Comments: A single specimen was collected in low coastal shrubs above the Nullarbor cliffs. *C. m. dualis* was reported from Old Eucla only 25 km W of our locality.⁷ Colour and pattern of the specimen generally conforms to Storr's description⁸ but differs in having distinct black edges to keels on all head scales (Fig. 1B).

Family: Scincidae. *Egernia coventryi* Storr.

Locality record: S. Aust: SAM R32711, 1.6 km N Cape Banks Lighthouse (37°58'S, 140°22'E).

Comments: A specimen of *E. coventryi* was collected in an Elliott trap in open scrub, closed sedgeland habitat. G. Shea (*in litt.*, 13.ii.1984) noted that five specimens of "*E. luctuosa*," the W.A. counterpart of *E. coventryi*, previously were deposited in the British Museum (Natural History) from "South Australia".

Shea wrote, "The locality is very suspect. The listing predates the description of *E. coventryi* so could be either *E. luctuosa* or *E. coventryi*." We have not examined the BM specimens and feel that the more recent finding is sufficiently important to warrant reporting as a new record for the State. The nearest locality previously recorded for this species is Portland, Victoria, 100 km E of the SA locality. Colour and pattern of the specimen (Fig. 1C) are bolder than reported in previous descriptions.¹¹

Egernia carinata Smith.

Locality records: S. Aust: SAM R2910, Ooldea (30°27'S, 131°50'E); SAM R2478, R9510, R10838-41, Flinders Island (33°43'S, 134°31'E); SAM R3062, Coralbigne HS (32°37'S, 136°21'E); SAM R3346, Penong (31°56'S, 133°01'E); SAM R 12727, Koonalda Cave (31°24'S, 129°50'E); SAM R19848, 1 km N. Inala rockhole Yumburra Cons. Park (31°46'S, 133°29'E); SAM R22977-78, AM R107937, WAM R70803-04, 15-17 km E SA/WA border (31°35'S, 129°40'E).

Comments: SAM specimens of *E. carinata* from SA were misplaced among the similar species, *E. striolata* (G. Shea, *in litt.*, 13.x.1983). *E. carinata* (Fig. 1D) differs from *E. striolata* in number of upper caudal scales (41-46 vs 56-64) and number of subcaudals minus expanded upper caudal scales (16-21 vs 3-7), respectively. The nomenclatural status of *E. carinata* is in doubt. Cogger *et al.*⁹ noted that "the holotype (and only specimen) of *E. richardi* (Peters) is identical in most respects to *Egernia carinata* Smith, 1939 from southern W.A. and over which its name would have precedence if the two are shown to be conspecific.

Lerista picturata baynesii Storr.

Locality records: S. Aust: AM R107936, 16 km E. SA/WA border (31°42'S, 129°02'E); SAM R23025-26, 1 km E SA/WA border (31°38'S, 129°01'E).

Comments: The two SAM specimens were collected from under coastal eucalypt leaf litter. The AM specimen was collected from the Nullarbor cliff edge, 0.2 km S of the Eyre Highway, in leaf litter beneath *Melaleuca* trees. On the same day, three specimens of *L. picturata edwardsae* (AM R107944-46) 42.3 km E. of the "Nullarbor Roadhouse", also were collected. This locality places *L. p. baynesii* and *L. p. edwardsae* within 200 km of each other and suggests that the two populations may contact along the coast rather than to the North of the Nullarbor Plain as suggested by Storr.¹⁶

Lerista xanthura Storr.

Locality records: S. Aust: SAM R19074, 3 km SW New Mulgaria HS (30°14'S, 137°39'E); SAM R19075, 15 km E Frome Downs HS (31°10'S, 139°58'E); SAM R20941, R20962-63, Olympic Dam area (Roxby Downs) (30°22'S, 136°56'E).

Comments: Cogger³ noted the distribution of *L. xanthura* as "Gibson Desert, WA. to southwestern NSW" but

questioned its range in S.A. Specimens of *L. xanthura* (R19074-75) were taken from sand dunes with low shrubs and *Casuarina* trees, nr Lake Frome. Other specimens (R20941, R20962-63) were caught in pitfall traps in similar habitats nr Roxby Downs. Scalation and colour pattern of these specimens followed Storr¹⁷ and Cogger.³

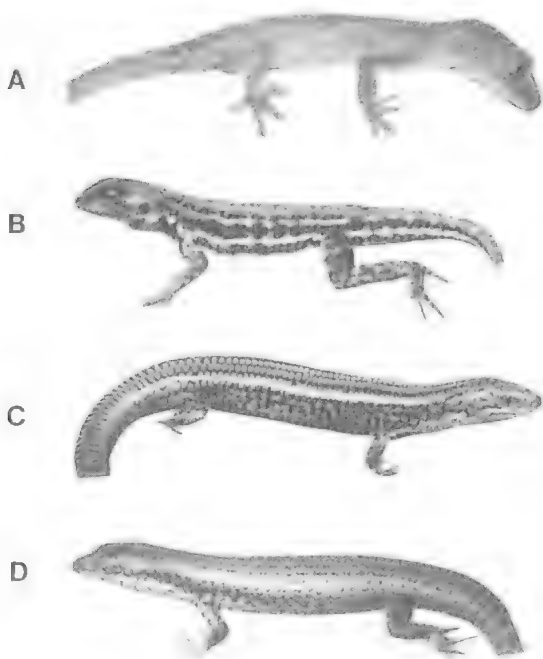


Fig. 1. A. *Diplodactylus williamsi*, B. *Ctenophorus maculatus dualis*, C. *Egernia coventryi*, D. *Egernia carinata*.

Notoscincus ornatus (Broom)

Locality record: S. Aust: SAM R17324, Mokari, Simpson Desert (26°19'S, 136°27'E).

Comments: This first specimen was collected on red sand dunes among canegrass and scrub nr rotten *Casuarina* trees. The range of this species now extends well into northern S.A.

Proablepharus reginae (Glauert)

Locality record: S. Aust: AM R17385, Mt Davies, Tomkinson Range (26°15'S, 129°16'E).

Comments: Although used to construct Australia-wide distribution maps^{1,2,3} this first record specimen of *P. reginae* from S.A. never was formally reported (G. Shea, *in litt.*, 13.ii.1984).

Family: Elapidae. *Simoselaps anomalus* (Sternfeld)

Locality record: S. Aust: SAM R17466, Serpentine Lakes (28°52'S, 129°11'E).

Comments: This specimen was collected during a survey of the "Unnamed Conservation Park" in extreme western S.A. Previously included as a subspecies of *S. bertholdi*, Storr¹⁸ elevated *anomalus* and *littoralis* to full species noting subsequently¹⁷ that "these 'subspecies' are in fact parapatric or marginally sympatric species." The S.A. record extends the range of *S. anomalus* 350 km S in W.A. and the N.T. to deep within the recognized range of *S. bertholdi*³, further confirming Storr's taxonomic assessment.¹⁸

We thank S. Berry, P. Bird, A. Edwards, J. Fowler, G. Harold, C. Harvey, M. Hutchinson, R. Hutchinson, K. Miller, B. Taverner, T. Morley, A. C. Robinson, R. Sadlier, S. Sarre, G. Shea, M. Thompson, R. Wells and J. White for their many contributions to this report. R. Ruehle prepared the photographs from colour slides. L. Schwaner typed the manuscript.

¹Cogger, H. G. (1975). "Reptiles and Amphibians of Australia" (Reed: Sydney.)

²— (1979). *Ibid.* 2nd Edtn.

³— (1983). *Ibid.* 3rd Edtn.

⁴Houston, T. F. (1973). Reptiles of South Australia, a brief synopsis. In: 'South Australian Year Book, 1973' (Govt Printer: Adelaide.)

⁵— (1978). "Dragon lizards and goannas of South Australia." *S. Aust. Mus. Spec. Ed. Bull. Ser.*, 84 pp.

⁶— & Tyler, M. J. (1979). In: Tyler, M. J., Twidale, C. R. & Ling, J. K. (eds) 'Natural History of Kangaroo Island' (R. Soc. S. Aust.: Adelaide.)

⁷Thompson, M. B. & Tyler, M. J. (1983). Reptiles and Amphibians. In: Tyler, M. J., Twidale, C. R., Ling, J. K. & Holmes, J. W. (Eds) 'Natural History of the South East' (Royal Soc. S. Aust.: Adelaide.)

⁸Waite, E. R. (1929). "The reptiles and amphibians of South Australia." (Govt Printer: Adelaide.)

⁹Storr, G. M. (1982). *Rec. W. Aust. Mus.* 10, 199-214.

¹⁰—, Smith, L. A. & Johnstone, R. E. (1983). "Lizards of Western Australia. II. Dragons & Monitors." (Univ. W.A. Press & W.A. Museum: Perth.)

¹¹Kluge, A. G. (1963). *Proc. Linn. Soc. N.S.W.* 88, 230-34.

¹²Storr, G. M., Hanlon, T. M. S. & Harold, G. (1981). *Rec. W. Aust. Mus.* 9, 23-39.

¹³— (1965). *J. Proc. R. Soc. W. Aust.* 48, 45-54.

¹⁴— (1978). *Rec. West. Aust. Mus.* 6, 147-87.

¹⁵Cogger, H. G., Cameron, E. E. & Cogger, H. M. (1983). "Zoological catalogue of Australia, I, Amphibia and Reptilia." (Australian Govt. Publishing Service: Canberra.)

¹⁶Storr, G. M. (1982). *Rec. W. Aust. Mus.* 10, 1-9.

¹⁷— (1976). *Ibid.* 4, 241-256.

¹⁸— (1967). *J. Proc. R. Soc. W. Aust.* 50, 80-92.

¹⁹— (1971). *Ibid.* 54, 59-75.

LIFE HISTORY OF THE NARROW-WINGED PEARL WHITE ELODINA PADUSA (HEWITSON) (LEPIDOPTERA: PAPILIONOIDEA)

BY A. R. MILNES, N. H. LUDBROOK, J. M. LINDSAY & B. J. COOPER

Summary

The pierid butterfly *Elodina padusa* (Fig. 1) occurs widely across northern Australia and south into central New South Wales and northern South Australia. It is commonly found close to its larval food plants, *Capparis* spp. A brief description of the early stage is given by Common & Waterhouse, but illustrations of these do not appear in any literature on Australian butterflies. A detailed description is provided here with illustrations and with notes on the life history, using material collected at Gammon Ranges National Park (30°30'S, 139°20'E), S. Aust.

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The pierid butterfly *Elodina padusa* (Fig. 1) occurs widely across northern Australia and south into central New South Wales and northern South Australia. It is commonly found close to its larval food plants, *Capparis* spp. A brief description of the early stages is given by Common & Waterhouse¹, but illustrations of these do not appear in any literature on Australian butterflies. A detailed description is provided here with illustrations and with notes on the life history, using material collected at Gammon Ranges National Park (30°30'S, 139°20'E), S. Aust.

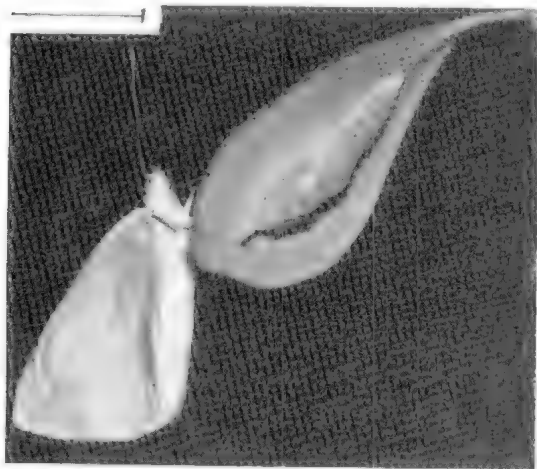


Fig. 1. *Elodina padusa*, recently emerged from its pupa. Bar scale 1 cm.

Larval food plant: *Capparis mitchellii* Lindley (native orange, Capparaceae), a shrub or small tree up to 4 m high and with ovate or broadly oblanceolate leaves.

Description of immature stages. Egg (Fig. 2A): height about 1 mm, diameter 0.5 mm; tapering uniformly to a blunt base and apex, with 16 vertical ridges of which some extend slightly beyond the apex and with numerous fine lateral lines; white at first, becoming pink or reddish.

First instar larva (Fig. 2B): length 2 mm; head yellow-green with setae projecting anteriorly; body pale yellow-green, each segment with raised subdorsal, lateral and sub-lateral grey or black spots, each with a long black seta curved anteriorly at first then becoming erect. On abdominal segments 1, 2 and 3 the spots are enclosed in a red area which sometimes extends dorsally across the segment, while some segments have a few additional raised spots and setae. Second instar larva (Fig. 2C): length 10 mm; head green with short setae; body pale green with a white dorsal line and numerous scattered setae, pro- and mesothorax and abdominal segments 2, 3, 4 and 8 with

dorsal red-brown tubercles, those on segment 2 most pronounced, posterior segment bifid.

Third instar larva (Fig. 2D): length 15 mm; head and body as in second instar but with dorsal red-brown tubercles usually prominent only on abdominal segments 2 and 8.

Fourth instar larva (Fig. 2E): length 20 mm, head and body as in third instar but prothorax with white dorsal area and several red-brown tubercles; dorsal line edged cream.

Pupa (Fig. 2F): length 18 mm; slender, pale green, anterior produced into a long tapering point; thorax with a dorsal ridge; abdomen with a faint dorsal and paired lateral white lines, tapering uniformly posteriorly, slightly flattened, ridged laterally and with three pairs of dorso-lateral brown spots.

Biology: Eggs are laid singly on either surface of the leaves of the food plant and occasionally on the stems. Young larvae make their first meal by eating a hole in the surface of a leaf, but in later instars larvae feed on the edges of leaves, their slender pale green bodies conforming cryptically with the eaten edge and thus providing some protection from predators and possibly parasitic insects. Pupation occurs on the leaves and stems of the food plant, the pupa being fastened by a cremaster and girdle. When attached to leaves the pupa is usually aligned with the central rib of the leaf and, as with the larva, the cryptic colour and shape make detection difficult.

Eggs collected in early March were reared in Adelaide and reached the adult butterfly stage an average of 29 days after eclosion. The larvae passed through four instars. Such a short cycle from egg to adult suggests that a number of generations of this butterfly may occur in a single year, or in a single summer season.

I thank the Wildlife Conservation Fund for financial assistance in field work, the National Parks and Wildlife Service for permission to collect material in Gammon Ranges National Park and A. E. Mitchell for the use of his vehicle.

¹Common, I. F. B. & Waterhouse, D. F. (1981). "Butterflies of Australia" Revised edition. (Angus and Robertson: Melbourne.)

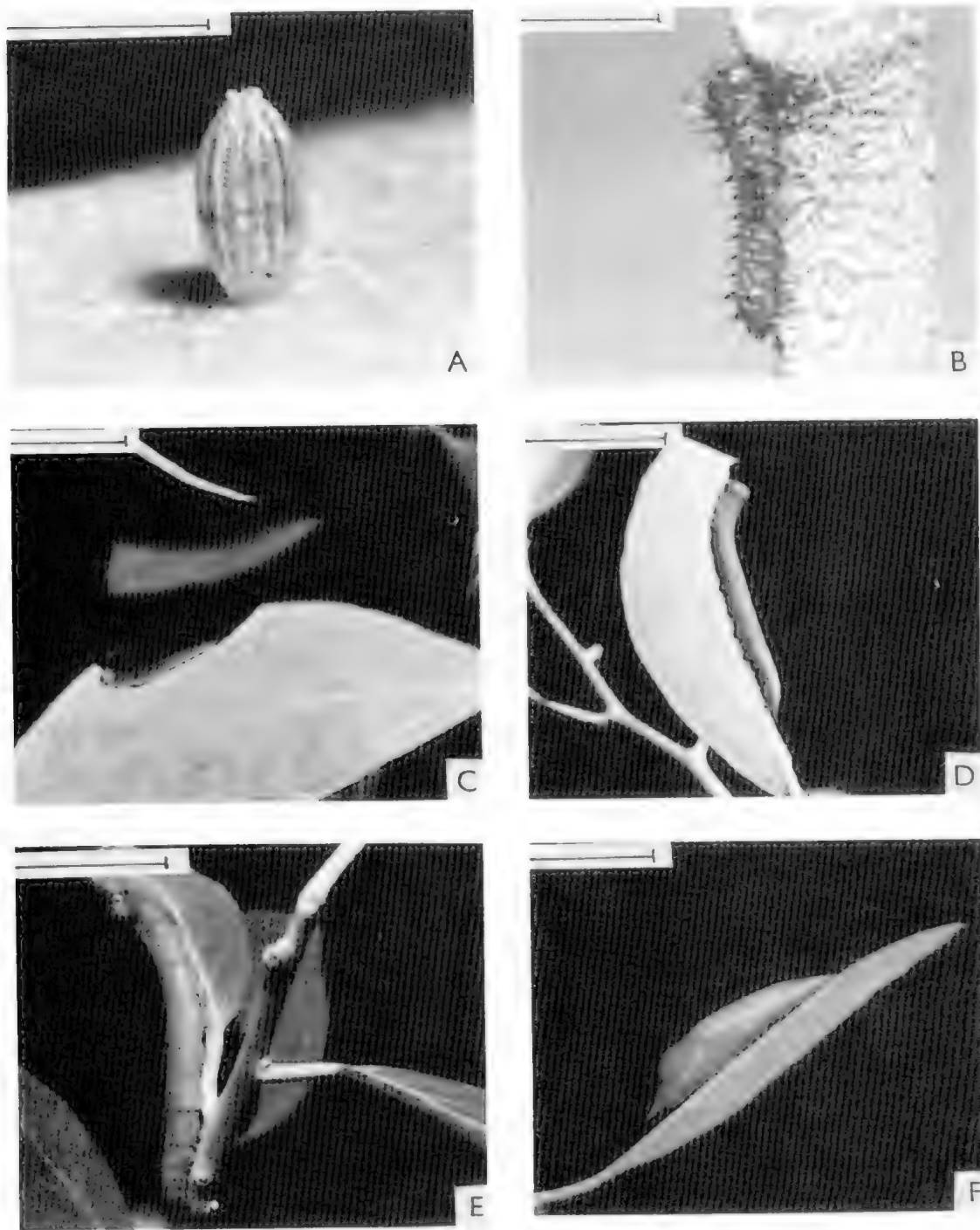


Fig. 2. *Elodina padusa*. A egg. B first instar larva. C second instar larva. D third instar larva. E fourth instar (mature) larva. F pupa. Bar scales A, B = 1 mm; C, D, E, F = 1 cm

NOTES ON THE REPRODUCTION OF NEPHRURUS DELEANI (REPTILIA: GEKKONIDAE)

BY STEVEN DELEAN

Summary

Reproductive biology of the knob-tailed geckos (*Nephurus* spp.) is largely known. Although the ecology of some *Nephurus* has been extensively studied in Western Australia, there has been only one report of clutch and egg sizes for this genus. Here we report the first successful hatching of eggs from a captive *Nephurus*.

NOTES ON THE REPRODUCTION OF *NEPHRURUS DELEANI* (REPTILIA: GEKKONIDAE)

Reproductive biology of the knob-tailed geckos (*Nephrurus* spp.) is largely unknown. Although the ecology of some *Nephrurus* has been extensively studied in Western Australia¹, there has been only one report of clutch and egg sizes for this genus.² Here we report the first successful hatching of eggs from a captive *Nephrurus*.

Nephrurus deleani is the only knob-tailed gecko endemic to South Australia, where it is restricted to the *Acacia* dominated sand dunes surrounding Pernatty Lagoon¹. On 24.x.1982 at 2015 hrs. we collected a gravid *N. deleani* (SVL 78 mm, weight 13.0 g) in sand dunes at the type locality of this species (Fig. 1). The specimen was retained to determine egg size, incubation time and hatchling size under laboratory conditions.

The specimen was placed in a small vivarium on a substrate of moistened Vermiculite and maintained at 20°C. On 30.x.1982, two eggs were found buried approximately 2 cm beneath the surface. These were weighed, measured, marked and placed in a sealed container in sterilized Vermiculite mixed with distilled water (100 ml water/150 g Vermiculite).⁴ The container was placed in a thermostatically controlled chamber, where the temperature range was 29°–30.5°C. The eggs were lightly sprayed fortnightly to prevent desiccation and measurements of egg sizes and mass were made regularly (Table 1). Approximately one week prior to emergence the



Fig. 2. Hatchling male *Nephrurus deleani* (SVL 36 mm, weight 1.9 g) with unhatched egg.

eggs appeared desiccated and although daily spraying was carried out the appearance of the eggs remained unchanged.

Hatchlings emerged on 25–26.xii.1982 after 55–56 days, incubation. Both specimens emerged from the egg immediately after completing a longitudinal slit in the egg shell. No part of the yolk sac was visible on either specimen.

The hatchlings were much darker than the adult female in colour and possessed a pale vertebral stripe which extended from the occiput to the tip of the tail (Fig. 2). The presence of this vertebral stripe, found only in juvenile *N. deleani*, previously led to some confusion between this species and *N. vertebralis*.³ Both hatchlings has a SVL of 4.5 mm less than the smallest SVL we have recorded from field collected specimens.

Unlike many other species of reptiles, no significant changes were noted in the size of either of the eggs during the incubation period (Table 1).

We have collected gravid specimens of this gecko in January, April, May and October, which indicates that *N. deleani* may reproduce opportunistically, rather than seasonally.

The Peter Rankin Trust Fund for Herpetology funded our field work. Michael Delean assisted in the recording of data and Winnie Feijen typed the manuscript. Terry Schwaner made constructive comments on the manuscript.

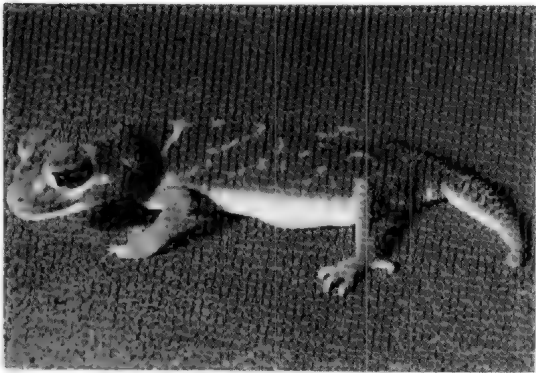


Fig. 1. Female *Nephrurus deleani* (SVL—78 mm, weight 13.0 g) 2 days before paturation.

TABLE 1. Length (L), width (W) and mass (M) of eggs, hatching dates and snout-vent length (SVL), tail length (TL), sex and weight of hatchling *Nephrurus deleani*. L, W, SVL and TL in mm, M in g.

Egg No.	Dates Measured						Dates Hatched (Dec. 1982)				SVL	TL	M	Sex
	24.x.1982		22.xi.1982		20.xii.1982									
	L	W	M	L	W	M	L	W	M					
1	25	23	2.5	24.8	13.9	2.4	24.8	13.7	2.5	25	36	16	1.9	♂
2	24.5	13.5	2.5	25.5	14.5	2.4	24.0	15.2	2.7	26	37	16	2.1	♂

- ¹Pianka, E. R. & Pianka, H. D. (1976). *Copeia*, 1976 (1), 125-142.
- ³Harvey, C. (1983). *Trans. R. Soc. S. Aust.* 107, 231-235.
- ²Gow, G. F. (1979). *N.T. Nat.* 1, 9-10.
- ⁴Barnett, B. (1982). *Vic. Herpetol. Soc. Newsl.* 1, 1-10.

STEVEN DELEAN, 49 Davenport Terrace, Seaview Downs, S. Aust., 5049 and CHRIS HARVEY, 20 Crozier Terrace, Oaklands Park, S. Aust., 5046.

CORRELATION OF THE UPPERMOST LATE PRECAMBRIAN SUCCESSION ACROSS THE TORRENS HINGE ZONE IN THE PORT AUGUSTA REGION OF SOUTH AUSTRALIA: A DISCUSSION

BY W. V. PREISS

Summary

In his recent paper, Plummer proposed new arguments in favour of resurrecting a correlation of the Simmens Quartzite and Corraberra Sandstone Members of the Tent Hill Formation (Wilpena Group) on the Stuart Shelf, with the Pound Subgroup of the Adelaide Geosyncline. This correlation, as well as previous ones proposed by the other authors quoted by Plummer, had been made at an early reconnaissance stage of mapping in both regions. Only those correlations published after 1965 were based on adequate knowledge of the regional stratigraphies of the Stuart Shelf and Flinders Ranges, but even so, the details of facies relationships on the Stuart Shelf did not become available until the extensive drilling by mineral exploration companies in the late 1970s and early 1980s.

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The criticism that the previous correlations were all based on lithostratigraphy is a little misplaced when Plummer's own arguments are (in the absence of independent evidence such as biostratigraphy, geochronology or palaeomagnetism), also entirely lithostratigraphic. It is therefore necessary to examine closely the criteria and assumptions on which his correlations are based.

In the course of studying the regional sedimentology and palaeogeography of the lower Wilpena Group in the Adelaide Geosyncline, Plummer² mapped a previously unrecognised local erosional contact between the ABC Range Quartzite and the overlying Bunyeruo Formation, near Buckaringa Gorge in the southern Flinders Ranges. Having visited this locality, I am happy to accept his mapping (Plummer², Fig. 4) as accurate. The same map indicates that just north of the erosional channel cut into the ABC Range Quartzite, the two units intertongue, from this relationship alone it therefore seems unreasonable to ascribe a regional significance to the erosional break, and to extend this disconformity westward on to the Stuart Shelf.

The only evidence presented by Plummer¹ for such an erosional break on the Stuart Shelf (the large lacuna in his Fig. 2) is based on a stratigraphic section of the Tregolana Shale, Corraberra Sandstone and Simmens Quartzite Members published by Thomson³. This section, based on outcrop, indicates clearly an upward transition from shale to sandstone, and may be confirmed by inspection of numerous drillcores from the Stuart Shelf. The apparent "sharp boundary separating the two shale units of the Tregolana Shale Member" pointed out by Plummer¹, is a cartographic peculiarity, since all lithological boundaries on this diagram are shown by a similar heavy line, and it was never intended to indicate a lithologic discontinuity (H. P. Thomson, pers. com., 1984). No new evidence from either outcrop or drillcore has been offered.

The presence of Bunyeruo Formation in the Wilkatana 1 Oil Bore is irrelevant to the discussion since the bore was not sufficiently deep to intersect the Bunyeruo/ABC

Range Quartzite contact. The existence of a disconformity here is therefore purely speculative.

Plummer does not state reasons, other than the postulated regional disconformity, why the simplest interpretation proposed by previous authors and recently summarised by Preiss⁴ is incorrect. This is particularly difficult to understand as the Wilpena Group of the Stuart Shelf is an upward coarsening sequence (locally overlain by a fine-grained unit, the Yarloo Shale), essentially similar to the regressive sequence he has described² from the lower Wilpena Group of the Flinders Ranges. The only significant difference seems to be the replacement of the Moorillah and Bayley Range Siltstone Members of the Brachina Formation by the cross-bedded, red, Corraberra Sandstone on the Stuart Shelf. However, red sandstones locally occur at the base of the ABC Range Quartzite, possibly representing tongues of Corraberra Sandstone. Moreover, no facies resembling the Wonoka Formation has been found on the Stuart Shelf. Plummer's correlation table (Fig. 2) implies that the Wonoka Formation passes laterally westwards into Bunyeruo Formation, but there is no direct evidence of this. Indeed, the Wonoka Formation is a laterally persistent unit, recently interpreted in part as a calcareous flysch facies⁵. The presence of limestone intraclasts in intraformational breccias suggests that its shallow-water marginal facies were also calcareous.

Plummer has neglected to account for the Yarloo Shale. It was first mapped by Johns⁶ overlying the Simmens (or Arctonua) Quartzite and disconformably overlain by the Cambrian Andamouka Limestone on the northeastern Stuart Shelf, and has been correlated with the Bunyeruo Formation⁶. The Yarloo shale, and its gradational passage down into facies that are typical of the ABC Range Quartzite, may be observed in the Amaco SCYW1A drillhole core (drilled near Yarra Yarra cliff at the northern end of Lake Torrens). This excellent section penetrates the whole stratigraphy from Cambrian redbeds down to the Sturtian glaciols. All intervening Adelaidean units can be identified confidently with the exception of the Wonoka Formation and Pound Subgroup. These are absent, either having been never deposited on the Stuart Shelf (they reflect an overall regressive phase of deposition, at least to the top of the Bonney Sandstone) or having been eroded in earliest Cambrian time.

In conclusion, although there is no proof of absolute synchronicity of the Stuart Shelf Wilpena Group with the lower Wilpena Group of the Flinders Ranges (up to and including the lower part of the Bunyeruo Formation) there are compelling reasons to consider them as part of the same depositional system, unrelated to the deposition of the Wonoka Formation and Pound Subgroup, which resulted from renewed tectonic activity⁷ and may have been confined to the Adelaide Geosyncline and parts of the Torrens Hinge Zone.

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- ¹**Plummer, P. S.** (1983). Trans. R. Soc. S. Aust. 107, 171-175.
- ²**Plummer, P. S.** (1978). Trans. R. Soc. S. Aust. 102, 25-38.
- ³**Thomson, B. P.** (1965). Q. geol. Notes, geol. Surv. S. Aust. 13, 4-5.
- ⁴**Preiss, W. V.** (Compiler), (1983). Adelaide Geosyncline and Stuart Shelf: Precambrian and Palaeozoic Geology (with special reference to the Adelaidean). Geological map, special series, 1:600 000. Geol. Surv. S. Aust.
- ⁵**Jenkins, R. J. F. & Gostin, V. A.** (1983). Abstracts, symposium "Adelaide Geosyncline sedimentary environments and tectonic settings", Geol. Soc. Aust. 10, 39-44.
- ⁶**Johns, R. K.** (1968). Bull. geol. Surv. S. Aust. 41.

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CORRELATION OF THE UPPERMOST LATE PRECAMBRIAN SUCCESSION ACROSS THE TORRENS HINGE ZONE IN THE PORT AUGUSTA REGION OF SOUTH AUSTRALIA: A REPLY

BY P. S. PLUMMER

Summary

The discussion by Preiss warrants comment on a number of points. Firstly, the accusation that the correlations by Plummer are purely lithostratigraphical is erroneous. By correlating palaeoenvironments into a palaeogeography, a chronological component is injected into the system. In sequences such as the Precambrian that are largely devoid of biostratigraphical, palaeomagnetic and direct age determinations, such correlations are the only hint available of time equivalence.

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The discussion by Preiss¹ warrants comment on a number of points.

Firstly, the accusation that the correlations by Plummer² are purely lithostratigraphical is erroneous. By correlating palaeoenvironments into a palaeogeography, a chronological component is injected into the system. In sequences such as the Precambrian that are largely devoid of biostratigraphical, palaeomagnetic and direct age determinations, such correlations are the only hint available of time equivalence.

The presence of the hitherto unrecognised unconformity at the ABC Range Quartzite/Bunyeroo Formation level is agreed to. However, Preiss reverts to a logic of layer-cake stratigraphy in an endeavour to lessen the significance of this horizon. Such logic is not applicable to the stable shelf/active basin setting under consideration. In such settings, shelf unconformities can frequently be time equivalent to thick basinal sedimentary packages. Such is the case here.

The lateral persistence of the Wonoka Formation is agreed to, but only within the context of the geosyncline. The Wonoka Formation is a basinal flysch facies, and hence not expected in its same form on the adjacent stable shelf. Here again, however, Preiss applies a layer-cake logic for his expectation of just such an equivalent facies.

Describing the sharp boundary separating the two shaly units of the Tregolana Shale Member as a "cartographic peculiarity", is surely not intended to be taken as a serious scientific argument!

Twice in his discussion Preiss refers to the lower Wilpena Group as representing a coarsening upward sequence, then

draws an equivalence with the coarsening upward Tent Hill Formation on the Stuart Shelf. It should be pointed out, however, that the upper Wilpena Group is also a coarsening upward sequence. Both sequences are, in fact, regressive, but the lower Wilpena Group sequence is regressive to the point that erosion occurred *within* the basin. In such a case, any time equivalence correlation with a similar regressive sequence on the adjacent stable shelf must be viewed with scepticism.

Finally, the only locally occurring sandy facies within the basal portion of the ABC Range Quartzite is a deep purple, heavy mineral rich, trough crossbedded, medium to coarse quartzite which originated in deltaic distributary channels. These are not typical Corraberra Sandstone facies, and hence highly unlikely to be the tongues that Preiss suggests.

In conclusion, it is agreed that "there is no proof of absolute synchronicity of the Stuart Shelf Wilpena Group" with the upper Wilpena Group in the Flinders Ranges, but the chronological component injected into the system by palaeoenvironmental correlations renders this synchronicity the most likely.

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²Plummer, P. S. (1983) Trans. R. Soc. S. Aust. 107, 171-175.

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EVIDENCE OF GASTRIC BROODING IN THE LEPTODACTYLID FROG RHEOBATRACHUS VITELLINUS

BY KEITH R. McDONALD & MICHAEL J. TYLER

Summary

The first record of gastric brooding in the Animal Kingdom was reported in the leptodactylid frog from *Rheobatrachus silus* Liem in 1974, and the first photographs of oral birth were published in 1981. The description of *R. vitellinus* includes morphological evidence of a close phylogenetic relationship to *R. silus*. Here we report that *R. vitellinus* also broods its young in its stomach and gives birth through its mouth.

EVIDENCE OF GASTRIC BROODING IN THE AUSTRALIAN LEPTODACTYLID FROG *RHEOBATRACHUS VITELLINUS*

The first record of gastric brooding in the Animal Kingdom was reported in the Australian leptodactylid frog from *Rheobatrachus silus* Liem in 1974¹, and the first photographs of oral birth were published in 1981². The description of *R. vitellinus*³ includes morphological evidence of a close phylogenetic relationship to *R. silus*. Here we report that *R. vitellinus* also broods its young in its stomach and gives birth through its mouth.

On 12.i.84 a single male and female *R. vitellinus* were collected at approximately 2130 hr in a creek bed of large boulders within complex notophyll vineforest in Eungella National Park, Queensland. The water temperature at the site was 19.4°C. The female was greatly distended, and during road transport to Mackay on 13.i.84 she began to give birth to young.

The first juvenile was born at 0700 hr and, during the next 27 minutes, 14 more were born individually or in twos or threes on nine occasions. These individuals were born underwater and it was noticed that the female opened her gape greater than 90°. The subsequent birth of babies was spaced out at less frequent intervals, with single individuals born as follows: 0811 hr, between 0855 and 0915 hr, between 1210 and 1219 hr, between 1630 and 1635 hr and between 2245 hr on 13.i.84 and 0600 hr on 14.i.84. The mother was despatched by air to Adelaide, and a further juvenile was born in transit sometime before 1655 hr.

At 1900 hr on 14.i.84 the mother was cooled and then packed in crushed ice prior to removal of the viscera for histological and biochemical studies. On removal of the entire alimentary canal a bulge was observed in the

stomach, and upon compression a further baby frog was expressed. The juvenile was placed in warm water and recovered consciousness 30 min. later.

The total number of young brooded by the mother was therefore 22, which is within the range for *R. silus* (18-25)⁴. The larger body size of *R. vitellinus*³ has not been accompanied by an increase in the number of young. However the snout-vent length of the young at birth (15.1-15.9 mm in two preserved specimens) is larger than the known range for *R. silus* (11.9-12.8 mm)⁴.

Rheobatrachus silus gives birth to young at the surface of the water. We remain uncertain whether the underwater birth of *R. vitellinus* was a natural phenomenon or a consequence of the artificial conditions in which the female was constrained.

The female on which these observations are based subsequently was cleared and stained for bone and cartilage and is a paratype (South Australian Museum R 25447)¹.

Field assistance was provided by Veron Hansen and Guy Chester, and helpful advice offered by Margaret Davies and Jeff Miller.

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COMMENT: WARDANG ISLAND – A REFUGE FOR MARGINOPHORA VERTEBRALIS?

BY A. P. BELPERIO AND C. V. MURRAY-WALLACE

Summary

Bone recently suggested that tests of *Marginopora vertebralis* found on the intertidal flat between Wardang Is. And Goose Is. are of recent origin, and that this species may be extant within the adjacent reef waters. This hypothesis was based on the fresh and uncemented appearance of individual specimens, on the MgCO_3 content of various samples, and on the apparent absence of outcropping (erosional) sources of older material. As part of ongoing studies into the stratigraphy and chronology of coastal Quaternary sediments of South Australia, we are examining the wider problem of reworking of Pleistocene bioclastic detritus into Holocene coastal sediments. Previous studies have demonstrated that reworking of older material is a significant process which must be considered, particularly where isotopic dating of the carbonate fraction of sediments is contemplated. One verified indicator of reworking is the presence of the bivalve *Anadara trapezia* in Holocene coastal sediments of S. Aust., and a similar conclusion has been assumed in the case of *M. vertebralis*. Our recent but unpublished data on the extent of amino acid racemisation in *M. vertebralis* found in Holocene strata from various areas of the State confirm that in each case, its presence also results from reworking of Pleistocene deposits.

COMMENT: WARDANG ISLAND—A REFUGE FOR *MARGINOPORA VERTEBRALIS*?

Bone¹ recently suggested that tests of *Marginopora vertebralis* found on the intertidal flat between Wardang Is. and Goose Is. are of recent origin, and that this species may be extant within the adjacent reef waters. This hypothesis was based on the fresh and uncemented appearance of individual specimens, on the MgCO_3 content of various samples, and on the apparent absence of outcropping (erosional) sources of older material. As part of ongoing studies into the stratigraphy and chronology of coastal Quaternary sediments of South Australia^{2,3,4,5}, we are examining the wider problem of reworking of Pleistocene bioclastic detritus into Holocene coastal sediments. Previous studies^{5,6,7,8} have demonstrated that reworking of older material is a significant process which must be considered, particularly where isotopic dating of the carbonate fraction of sediments is contemplated. One verified indicator of reworking is the presence of the bivalve *Anadara trapezia* in Holocene coastal sediments of S. Aust., and a similar conclusion has been assumed in the case of *M. vertebralis*¹. Our recent but unpublished data on the extent of amino acid racemisation in *M. vertebralis* found in Holocene strata from various areas of the State confirm that in each case, its presence also results from reworking of Pleistocene deposits.

To test the validity of Bone's hypothesis for Wardang Island, we have examined the Wardang Island reef site, and have used radiocarbon¹ and amino acid racemisation⁹ dating techniques on the samples collected.

The results show that the reef connecting Wardang Is. and Gooose Is., rather than being modern¹, is of Pleistocene age (Table 1). The surface of this reef is exposed at low tide and is mantled with a thin veneer (mostly <10 cm) of recent intertidal sand. The reef rock comprises

poorly sorted and weakly cemented bioclastic detritus, including numerous specimens of *M. vertebralis* up to 8 mm in diameter. Detritus from the crumbling seaward reef edge, including *M. vertebralis*, is swept over the reef surface and is the major source of the sediment of the intertidal veneer. Thus the "modern" intertidal veneer is largely composed of reworked Pleistocene skeletal detritus (lithoskels) and the age indicated by radiocarbon data (Table 1) is the "average age" of the skeletal constituents which make up the sediment. Individual fragments of the crumbling reef rock are visibly calccreted. However evidence of cementation and calcretization enveloping individual grains is apparently reduced and eventually eliminated by continual abrasion in the intertidal environment. In particular, specimens of *M. vertebralis* have secondary carbonate infillings progressively removed with distance landwards away from the reef edge, hence their "fresh" and "uncemented" appearance.

Amino acid racemisation measurements were also undertaken on *M. vertebralis* extracted from the reef rock (Table 2). Other specimens of known age from northern Spencer Gulf (Late Pleistocene)^{1,1} and the Great Barrier Reef (Recent) provide a basis for calibration. The foraminifera extracted from the Wardang Is. reef rock are clearly of Late Pleistocene age (ca. 110 000 yrs by analogy with the northern Spencer Gulf sample¹). Amino acid racemisation measurements could not be undertaken on the foraminifera loose on the tidal flat as bacterial and algal contamination penetrates the porous skeletal framework and cannot be satisfactorily removed.

We conclude that the specimens of *M. vertebralis* found on the tidal flat between Wardang Is. and Gooose Is. are derived from erosion of underlying weakly cemented

TABLE 1. Radiocarbon measurements on samples from Wardang Island.

Sample	Fraction Dated	Radiocarbon Age	Geological Age
6329RS75 Reef rock	Bulk carbonate	30 800 \pm 750/700 yrs ¹	Late Pleistocene
6329RS76 Intertidal sand	Bulk sediment	6 290 \pm 90 yrs ²	Holocene

¹ An "apparent age" resulting from the incorporation of some modern carbon into Late Pleistocene (Glanville Fm.) sediment.

² An "average age" resulting from physical intermixing of Late Pleistocene lithoskels with modern skeletal detritus.

TABLE 2. Extent of amino acid racemisation in samples of *Marginopora vertebralis* ("Total hydrolysate" D/L ratios of alanine, proline and aspartic acid).

Locality	No. of analyses	Amino acid D/L ratios			Geological Age
		ALA	PRO	ASP	
Great Barrier Reef	3	0.06	0.07	0.14	Holocene
Upper Spencer Gulf	1	0.25	0.29	0.37	Late Pleistocene
Wardang Island	2	0.25	0.27	0.32	

Pleistocene marine sediments. Consequently it is unnecessary, and is most likely incorrect, to invoke an hypothesis that *M. vertebralis* is extant in the adjacent waters.

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